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DEVELOPMENT OF AN AIRCRAFT MANEUVER
LOAD SPECTRUM BASED ON VGH DATA

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JULY 1980

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stress level, the probability density function for stress and the stress spectrum. The aircraft spectrum is derived from the assumption that the aircraft test loads derived from a linear combination of balanced loading conditions will provide a good simulation of the stress history at and "between" the control points. The application of the program to new designs (mission analysis) and to tracking can be made without modification. The computer program for this calculation is included along with a sample problem. As an example of an application of this program, the stress exceedance functions for a control point on the wing of the F-4 are shown that were computed from the VGII data accumulated over a period of one year.

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FOREWARD

This report was prepared by John W. Lincoln, Structures Division of the Directorate of Flight Systems Engineering. The work was done as a research and development task to assist in the spectrum development work for the F-4 durability and damage tolerance assessment.

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LIST OF SYMBOLS

N_{v_i}	The number of indicated airspeed intervals in the VGH histogram
N_{n_z}	The number of normal load factor intervals in the VGH histogram
N_h	The number of altitude intervals in the VGH histogram
N_w	The number of weight intervals in the VGH histogram
v_i	Indicated airspeed for the VGH histogram intervals
n_{z_i}	Normal load factor for the VGH histogram intervals
h_i	Altitude for the VGH histogram intervals
w_i	Aircraft weight for the VGH histogram intervals
H_j	The VGH histogram
N_t	The total number of load occurrences in the VGH histogram
P_j	The joint probability density function derived from the VGH histogram
$N_{v_i}^R$	The number of intervals in a refinement of an indicated airspeed interval in the VGH histogram
$N_{n_z}^R$	The number of intervals in a refinement of a normal load factor interval in the VGH histogram
N_h^R	The number of intervals in a refinement of an altitude interval in the VGH histogram
N_w^R	The number of intervals in a refinement of a weight interval in the VGH histogram
V_i	A surface, the ordinates of which are indicated airspeeds for determining the stress at a control point
N_z	A surface, the ordinates of which are normal load factors for determining the stress at a control point

H	A surface, the ordinates of which are altitudes for determining the stress at a control point
W	A surface, the ordinates of which are weights for determining the stress at a control point
\hat{P}_J	The joint probability density function for the refined VGH histogram
N_p	The number of control points on the aircraft structure used in the derivation of the fatigue spectrum
P_{ψ}^a	The cumulative probability for the stress at the ath control point
$P_{D_{\psi}}^a$	The probability density function for the stress at the ath control point
A_{cb}^a	The stress for the ath load level at the bth point in the sky and the cth control point
r_c^a	The fatigue test stress for the ath load level and the cth control point
α_{α}^{ab}	Scaling coefficients for the ath load level and the bth point in the sky
ϕ^a	A surface (generated from the surface P_J) from which P_{ψ}^a can be determined for ath control point
ψ^a	The stress surface for the ath control point
S^a	A set of ordinates of the graph 1 - P_{ψ}^a
$S^a(i)$	The ith member of S^a

SECTION I

INTRODUCTION

In the application of the mission analysis required by MIL-A-008866A (USAF) to fighter and attack aircraft a problem arises in the selection of the point in the sky (velocity, altitude, and weight) for the load factor spectrum for the combat segment of the mission. It can be shown that in many cases important differences in the spectrum can be obtained from two "reasonable" point selections.

The problem has been particularly severe on some existing aircraft in that a ten percent shift in the stress spectrum can produce a factor of two change in life. Therefore, when it is considered that essentially all of the fatigue damage for fighter and attack aircraft is done in the combat segment, this part of the mission deserves special attention.

From an examination of available VGH data, it is evident that in both the air-to-air and air-to-ground operations a fairly wide variation in velocity, altitude, and weight is observed. Therefore, it would be surprising if a single point in the sky would provide an accurate prediction of the stress spectrum for a control point. This is even more evident for those aircraft which experience non-linearities in the aerodynamic data (i.e., tip stall).

One possible solution is to use multiple points in the sky for this calculation. This can be effectively accomplished by taking the points in the sky and their relative frequency of occurrence that are obtained from that portion of the fleet that is equipped with multichannel recorders (twenty percent of the fleet, which is consistent with current policy, is believed to be an adequate sample). This can be done by taking the VGH histogram (the relative frequency of airspeed, normal load factor, altitude, and weight) and dividing by the total number of load occurrences to obtain the probability that a load will occur in a given interval of airspeed, normal load factor, altitude, and weight. A stress level is selected and a summation is made for each such probability where the corresponding stress at the midpoint of the interval of airspeed, etc, is greater than the selected stress level. This computation produces the cumulative probability of exceeding a stress level. Since the intervals used for the data collection were not designed for this calculation, a provision is made to subdivide the intervals to improve the accuracy of the calculation. This technique is explained in Section III. From the cumulative

probability, the number of stress exceedances per hour, the probability density function, and the stress spectrum can be obtained.

Having the functions referred to above for a number of control points that is adequate to cover the aircraft structure (this number may have to be obtained by trial and error), one may generate the full scale aircraft spectrum by assuming that an arbitrary loading at the control points of the structure can be derived from a linear combination of the loading imposed by balanced load conditions. If N_p control points are used, then N_p balanced load conditions are used to represent the control point load. The use of "representative" balanced load conditions should provide a satisfactory interpolation between control points. These intermediate points should be spot checked against the true spectrum to see if the control point coverage is adequate.

Of course, for a new design, the VGH data does not exist and consequently direct application of this method is impossible. In some cases it will be possible to overcome this difficulty by taking existing VGH data from older aircraft and by use of judgement adapt it to this procedure. In any event, the method should be applied when the proper data becomes available so that by suitable tests and analysis the appropriate changes may be made in the aircraft life predictions.

One important application of this procedure is fighter/attack tracking. The unusual technique is to use the fleet counting accelerometer data and compute the stress for a single point in the sky that is believed to be representative of the particular mission flown (i.e., air-to-air or air-to-ground). In lieu of this approach, one could compute from the VGH data the conditional probability of exceeding a stress given the normal load factor. If this function were available, it would be possible to track to any desired probability on even multiple probability levels depending on what results are desired. This function can be generated from this program by setting all occurrences equal to zero except those that fall in the desired load factor interval. The high positive and low negative load factors may require an extrapolation from neighboring load factors because there may be too few data points to adequately describe these functions.

The program that is discussed in this report is based on the load occurrences in the VGH histogram being dependent on indicated airspeed, normal load factor, altitude, and weight. The stress function is based on the same quantities. An immediate alternate that is

included is to use equivalent load factor instead of load factor. This removes the weight dependency and considerably reduces the magnitude of the input. This option is included in the computer program described in the text. Other alternates that could be obtained by a simple modification of the program are listed as follows:

VGH data based on	Stress function based on
1. Indicated airspeed, normal load factor, altitude, and weight.	Mach no., normal load factor, altitude, and weight.
2. Mach no., normal load factor, altitude, and weight.	Mach no., normal load factor, altitude, and weight.
3. Equivalent airspeed, normal load factor, and weight	Equivalent airspeed, normal load factor, and weight.

The extension of this program to include other degrees of freedom for the aircraft is immediately evident. The major difficulty is the management of the input data required for the load occurrences and the stress function.

SECTION II

ANALYTICAL DERIVATION OF THE SPECTRUM

The first step in the derivation of the fatigue spectrum is to solve for the stress probability distribution function. This requires that the histogram of occurrences in intervals of indicated airspeed, load factor, altitude, and weight be defined. To do this suppose that each of N_{v_i} , N_{n_z} , N_h , and N_w is a positive integer and

- (1) v_{ij} is a simple graph such that the x-projection of v_{ij} is the set of integers in $[1, N_{v_i} + 1]$ and if i is an integer in $[1, N_{v_i} + 1]$ and $i + 1$ is in $[1, N_{v_i} + 1]$ then the indicated airspeed $v_{ij}(i)$ is less than the indicated airspeed $v_{ij}(i + 1)$
- (2) n_{z_i} is a simple graph such that the x-projection of n_{z_i} is the set of integers in $[1, N_{n_z} + 1]$ and if j is an integer in $[1, N_{n_z} + 1]$ and $j + 1$ is in $[1, N_{n_z} + 1]$ then the normal load factor $n_{z_i}(j)$, is less than the normal load factor $n_{z_i}(j + 1)$
- (3) h_i is a simple graph such that the x-projection of h_i is the set of integers in $[1, N_h + 1]$ and if k is an integer in $[1, N_h + 1]$ and $k + 1$ is in $[1, N_h + 1]$ then the altitude $h_i(k)$, is less than the altitude $h_i(k + 1)$
- (4) w_i is a simple graph such that the x-projection of w_i is the set of integers in $[1, N_w + 1]$ and if m is an integer in $[1, N_w + 1]$ and $m + 1$ is in $[1, N_w + 1]$ the weight $w_i(m)$, is less than the weight $w_i(m + 1)$

Further, suppose H_J is a simple surface such that

$[v_{ii}(i), n_{z_i}(j), h_i(k), w_i(m), H_J(v_{ii}(i), n_{z_i}(j), h_i(k), w_i(m))]$ is a point of H_J only if

- (1) i is in $[1, N_{v_i}]$, j is in $[1, N_{n_z}]$, k is in $[1, N_h]$, m is in $[1, N_w]$ and
- (2) $H_J(v_{ii}(i), n_{z_i}(j), h_i(k), w_i(m))$ is the number of "load occurrences" in the rectangular interval $[v_{ii}(i), v_{ii}(i+1); n_{z_i}(j), n_{z_i}(j+1); h_i(k), h_i(k+1); w_i(m), w_i(m+1)]$ and these load occurrences are assumed to be uniformly distributed within the rectangular interval.

The surface H_J is called the VGH histogram for v_{ii} , n_{z_i} , h_i , and w_i .

The total number of load occurrences included in the VGH histogram H_J is

$$N_t = \sum_{i=1}^{N_{v_i}} \sum_{j=1}^{N_{n_z}} \sum_{k=1}^{N_h} \sum_{m=1}^{N_w} H_J(v_{ii}(i), n_{z_i}(j), h_i(k), w_i(m))$$

Therefore, by definition, the probability that the indicated airspeed, normal load factor, altitude, and weight is in the rectangular interval $[v_{ii}(i), v_{ii}(i+1); n_{z_i}(i), n_{z_i}(j+1); h_i(k), h_i(k+1); w_i(m), w_i(m+1)]$ is

$$P_J(i, j, k, m) = \frac{H_J(v_{ii}(i), n_{z_i}(j), h_i(k), w_i(m))}{N_t}$$

Now suppose that if i is in $[1, N_{V_i} - 1]$ then the interval $[v_{ii}(i), v_{ii}(i + 1)]$ is covered by $N_{V_i}^R$ equal intervals, if j is in $[1, N_{n_z} - 1]$ then $[n_{z_i}(j), n_{z_i}(j + 1)]$ is covered by $N_{n_z}^R$ equal intervals, if k is in $[1, N_h - 1]$ then $[h_i(k), h_i(k + 1)]$ is covered by N_h^R equal intervals, and if m is in $[1, N_w - 1]$ then $[w_i(m), w_i(m + 1)]$ is covered by N_w^R equal intervals.

Since it was supposed that the load occurrences are within the rectangular interval $[v_{ii}(i), v_{ii}(i + 1); n_{z_i}(j), n_{z_i}(j + 1); h_i(k), h_i(k + 1); w_i(m), w_i(m + 1)]$ then the probability that the indicated airspeed, normal load factor, altitude, and weight is in the rectangular interval

$$\begin{aligned} & [v_{ii}(i), v_{ii}(i) + \frac{v_{ii}(i + 1) - v_{ii}(i)}{N_{V_i}^R}; \\ & n_{z_i}(j), n_{z_i}(j) + \frac{n_{z_i}(j + 1) - n_{z_i}(j)}{N_{n_z}^R}; \\ & h_i(k), h_i(k) + \frac{h_i(k + 1) - h_i(k)}{N_h^R}; \\ & w_i(m), w_i(m) + \frac{w_i(m + 1) - w_i(m)}{N_w^R}] \end{aligned}$$

is

$$\hat{P}_j(i, j, k, m) = \frac{H_j(v_{ii}(i), n_{z_i}(j), h_i(k), w_i(m))}{N_t N_{V_i}^R N_{n_z}^R N_h^R N_w^R}$$

(1) Now suppose that V_i is a simple surface such that the x-y projection of V_i is the set of integers in the rectangular

interval $[1, N_{v_i} + 1; 1, N_{v_i}^R]$ and if i and $i + 1$ are integers

in $[1, N_{v_i} + 1]$ and i_R is an integer in $[1, N_{v_i}^R]$ then

$$v_i(i, i_R) = v_{ii}(i) + \left(\frac{i_R - 0.5}{N_{v_i}^R} \right) (v_{ii}(i + 1) - v_{ii}(i))$$

(2) N_z is a simple surface such that the x - y projection of N_z is the set of integers in the rectangular interval $[1, N_{n_z} + 1; 1, N_{n_z}^R]$ and if j , and $j + 1$ are integers in

$[1, N_{n_z} + 1]$ and jr is an integer in $[1, N_{n_z}^R]$ then

$$N_z(j, j_R) = n_{z_i}(j) + \left(\frac{j_R - 0.5}{N_{n_z}^R} \right) (n_{z_i}(j + 1) - n_{z_i}(j))$$

(3) H is a simple surface such that the x , y projection of H is the set of integers in the rectangular interval $[1, N_h + 1; 1, N_h^R]$ and if k and $k + 1$ are integers in $[1, N_h + 1]$ and

k_R is an integer in $[1, N_h^R]$ then

$$H(k, k_R) = h_i(k) + \left(\frac{k_R - 0.5}{N_h^R} \right) (h_i(k + 1) - h_i(k))$$

(4) W is a simple surface such that the x , y projection of W is the set of integers in the rectangular interval $[1, N_w + 1; 1, N_w^R]$ and if m and $m + 1$ are integers in $[1, N_w + 1]$

and m_R is an integer in $[1, N_w^R]$ then

$$W(m, m_R) = w_i(m) + \left(\frac{m_R - 0.5}{N_w^R} \right) (w_i(m + 1) - w_i(m))$$

The assumption is made that the stress at a point in the structure depends only on the indicated airspeed, normal load factor, altitude and weight. Therefore, if it is supposed that each of a and N_p is a positive integer such that a is in $[1, N_p]$

and ψ^a is a simple surface such that $(V_i(i, i_R), N_z(j, j_R), H(k, k_R), W(m, m_R), \psi^a(V_i(i, i_R), N_z(j, j_R), H(k, k_R), W(m, m_R))$ is a point of ψ^a only if i is in $[1, N_{V_i} + 1]$, i_R is in $[1, N_{V_i}^R]$, \dots, m is in $[1, N_w + 1]$, m_R is in $[1, N_w^R]$ and $\psi^a(V_i(i, i_R), N_z(j, j_R), H(k, k_R), W(m, m_R))$ is the stress for the a th control point corresponding to the indicated airspeed $V_i(i, i_R)$, the normal load factor $N_z(j, j_R)$, the altitude $H(k, k_R)$, and the weight $W(m, m_R)$.

The surfaces ψ^a and \hat{P}_j are used in the calculation of the cumulative probability of exceeding a given stress as follows: Suppose that N_{Γ_L} is a positive integer and Γ_L is a uniformly increasing sequence with x -projection $[1, N_{\Gamma_L}]$ and ϕ^a is a simple surface such that

$$(1) \quad \phi^a(i, j, k, m, i_R, j_R, k_R, m_R) = \hat{P}_j(i, j, k, m) \\ \text{if } \psi^a(V_i(i, i_R), N_z(j, j_R), H(k, k_R), W(m, m_R)) > \Gamma_L(b)$$

$$(2) \quad \phi^a(i, j, k, m, i_R, j_R, k_R, m_R) = 0 \\ \text{if } \psi^a(V_i(i, i_R), N_z(j, j_R), H(k, k_R), W(m, m_R)) \leq \Gamma_L(b)$$

Therefore, the probability that the stress is greater than $\Gamma_L(b)$ is

$$P_{\psi^a}(\Gamma_L(b)) = \sum_{i=1}^{N_{V_i}} \sum_{j=1}^{N_{N_z}} \sum_{k=1}^{N_h} \sum_{m=1}^{N_w} \sum_{i_R=1}^{N_{V_i}^R} \sum_{j_R=1}^{N_{N_z}^R} \sum_{k_R=1}^{N_h^R} \sum_{m_R=1}^{N_w^R} \phi^a(i, j, k, m, i_R, j_R, k_R, m_R)$$

The probability density function $P_{D_{\psi^a}}$ is the derivative of the cumulative probability function P_{ψ^a} . This derivative is computed as follows: Suppose a is an integer in $[1, N_p]$ and that ζ^a is a simple graph with x -projection the interval $[1, N_{\Gamma_L}]$ such that

(1) if b is an integer in $[1, N_{\Gamma_L}]$ then $\zeta^a(b) = P_{D_\Psi}a(b)$ and

(2) if c is a number in $[b, b + 2]$ there exists a u_1, u_2 ,
and u_3 such that $\zeta^a(c) + u_1c^2 + u_2c + u_3$ where u_1, u_2 ,
 u_3 are determined from the equations

$$\begin{aligned}\zeta^a(b) &= b^2 & b & 1 & u_1 \\ \zeta^a(b+1) &= (b+1)^2 & (b+1) & 1 & u_2 \\ \zeta^a(b+2) &= (b+2)^2 & (b+2) & 1 & u_3\end{aligned}$$

Therefore

(1) if $b = 1$

$$P_{D_\Psi}a(1) = 2u_1 \Gamma_L(1) + u_2$$

$$P_{D_\Psi}a(2) = 2u_1 \Gamma_L(1) + u_2$$

(2) if b is in $[2, N_{\Gamma_L} - 3]$

$$P_{D_\Psi}a(b+1) = 2u_1 \Gamma_L(b+1) + u_2$$

(3) if $b = N_{\Gamma_L} - 2$

$$P_{D_\Psi}a(N_{\Gamma_L} - 1) = 2u_1 \Gamma_L(N_{\Gamma_L} - 1) + u_2$$

$$P_{D_\Psi}a(N_{\Gamma_L}) = 2u_1 \Gamma_L(N_{\Gamma_L}) + u_2$$

The next step in the derivation of the fatigue loading spectrum is to determine the stress and the frequency of that stress in the spectrum. This is done by an indirect process as shown below. Suppose that the fatigue test spectrum is to be composed of N cycles at M stress levels. Further, suppose that a is a positive integer in $[1, N_p]$ and S^a is a sequence of M numbers such that $s^a(i)$ and $s^a(j)$ are members of S^a only if $0 < s^a(i) < s^a(j) < 1$ and $i < j$.

Therefore, each member of S^a corresponds to an ordinate of the graph $1-P_\psi a$. The M abscissas corresponding to these M ordinates are defined as the M stress levels of the spectrum for the a th control point. The graph $1-P_\psi a$ is known at N_{Γ_L} points. Consequently, an approximation to $1-P_\psi a$ must be found in order to compute the spectrum stress levels. Suppose β is a simple graph with x -projection the interval $[\Gamma_L(1), \Gamma_L(N_{\Gamma_L})]$ and if k is in $[1, N_{\Gamma_L}]$ then $\beta(\Gamma_L(k)) = 1-P_\psi a(\Gamma_L(k))$. Further, suppose that if $i-1$, i , and $i+1$ are in $[1, N_{\Gamma_L}]$, δ_L is $\Gamma_L(k+1) - \Gamma_L(k)$, and x is in $[-\delta_L, \delta_L]$ then

$$\beta(x + \Gamma_L(k)) = [1 \frac{x}{\delta_L} \frac{(x)}{\delta_L}^2] \begin{bmatrix} 0 & 1 & 0 \\ -\frac{1}{2} & 0 & \frac{1}{2} \\ \frac{1}{2} & -1 & \frac{1}{2} \end{bmatrix} \begin{bmatrix} \beta(\Gamma_L(k-1)) \\ \beta(\Gamma_L(k)) \\ \beta(\Gamma_L(k+1)) \end{bmatrix}$$

It follows then that if i is in $[1, M]$ there exists an integer k such that $P_\psi a(\Gamma_L(k-1)) \leq s^a(i) \leq P_\psi a(\Gamma_L(k))$ and a number x such that $\beta(x + \Gamma_L(k)) = s^a(i)$. The number x is obtained from a solution of a quadratic equation and $x + \Gamma_L(k)$ is the stress corresponding to $s^a(i)$.

The fraction of the N cycles, n_i , that are associated with the i th stress level is defined as follows:

$$n_1 = \frac{s(1) + s(2)}{2}$$

$$n_i = \frac{s(i+1) - s(i-1)}{2} \quad 1 < i < M$$

$$n_M = 1 - \frac{(s(M) + s(M-1))}{2}$$

It follows then that if i is in $[1, M]$ and if the sequence S^a is used for each of the control points then there will be an equal number of loading cycles for the i th load level for each of the control points.

The final step is to determine a set of coefficients which when multiplied by the stresses corresponding to balanced load conditions for the aircraft will produce the desired stress levels at the aircraft control points. Suppose a is a positive integer in $[1, M]$, b is a positive integer in $[1, N_p]$, and c is a positive integer in $[1, N_p]$. Therefore, if A_{cb}^a is the stress for the a th load level at the b th point in the sky and the c th control point and r_c^a is the stress desired in the fatigue test for the a th load level and the c th control point then there exists a set of coefficients α_{ab} such that $r_c^a = A_{cb}^a \alpha_{ab}$.

SECTION III

DESCRIPTION OF THE COMPUTER PROGRAM

1 NOTATION

The right hand side of the following relations are defined in Section II.

$$NT421 = N_{v_i}$$

$$NT422 = N_{n_z}$$

$$NT423 = N_h$$

$$NT424 = N_w$$

$$NT = N_t$$

$$PJT = \hat{P}_j$$

$$NRVI = N_{v_i}^R$$

$$NRNZ = N_{n_z}^R$$

$$NRH = N_h^R$$

$$NRW = N_w^R$$

$$VII = v_{ii}$$

$$NZI = n_{z_i}$$

$$HI = h_i$$

$$WI = w_i$$

$$VI = v_i$$

$$NZ = N_z$$

$$H = H$$

$$W = W$$

$$NPS = N_p$$

$$PPSI = P_{\psi}a \text{ (The } a \text{ is not explicitly identified in the program)}$$

$$PDPSI = P_{D_{\psi}a} \text{ (The } a \text{ is not explicitly identified in the program)}$$

$$PS = A$$

$PLD = \Gamma$
 $ALPHA = \alpha$
 $FVI = v_{ii} (N_{v_i} + 1)$
 $FNZ = n_{z_i} (N_{n_z} + 1)$
 $FH = h_i (N_h + 1)$
 $FW = w_i (N_w + 1)$
 $FACT\varnothing R$ - Stress scaling factor. $FACT\varnothing R = 1$ unless otherwise specified.
 $H\varnothing URS$ - The number of hours of data in the VGH histogram
 $PSIL = \Gamma_L$
 $AREAN = s^a$
 $DELTA = \delta_L$
 $APDPSI(I) = 1.0 - PPSI(I)$
 $PSILL(I)$ - The stress level that is the abscissa of the point of $PPSI$ whose ordinate is $AREAN(I)$
 $FRAC(I)$ - The fraction of the total number of cycles in the spectrum that correspond to $PSILL$
 $NPSIL = N_{\Gamma_L}$
 $NPSILL = M$
 $EXCEED(I)$ - The number of exceedances per hour of the stress $PSIL(I)$
 $NZERO$ - Control number to zero the input numbers at the start of a run and then prevent them from being zeroed between cases
 $NPSCT$ - Control number for counting the number of control points for which a spectrum has been computed in a single run

2 INTERPOLATION PROCEDURE

Since the stress is initially calculated for only a finite set of points on the stress surface, an assumption must be made to determine the stress for a given indicated airspeed, normal load factor, altitude, and weight. Specifically, the problem may be expressed as follows: Given that $NT421, NT422, NT423, NT424, NRV1, NRNZ, NRH$, and NRW is a positive integer and I is in $[1, NT421]$, J is in $[1, NT422]$, K is in $[1, NT423]$, M is in $[1, NT424]$, IR is in $[1, NRV1]$, JR is in $[1, NRNZ]$, KR is in $[1, NRH]$, MR is in $[1, NRW]$ and a is in $[1, N_p]$ it is required to create an approximation in the form

$\xi^a(I, J, K, M, IR, JR, KR, MR) =$
 $\Xi^a(VI(I, IR), NZ(J, JR), H(K, KR), W(M, MR))$
 for the stress as expressed by
 $\psi^a(I, J, K, M, IR, JR, KR, MR) =$
 $\Psi^a(VI(I, IR), NZ(J, JR), H(K, KR), W(M, MR))$

where Ξ^a is a ruled surface based on $2^4 = 16$ points of Ψ^a . The method of choosing these 16 points and the calculation of the stress approximation is described below.

The first step is to define the function TABLE which contains the projections and ordinates of the Ψ^a surface.

Suppose each of NTAB1, NTAB2, NTAB3, and NTAB4 is a positive integer and that

$NN12 = NTAB1 + NTAB2$
 $NN13 = NN12 + NTAB3$
 $NN14 = NN13 + NTAB4$
 $NP = NTAB1 \cdot NTAB2 \cdot NTAB3 \cdot NTAB4$
 $NF = NN14 + NP$

Further, suppose that TABLE is a simple graph such that the x-projection of TABLE is the set of integers in the interval $[1, NF]$ and each of I1, I2, I3, and I4 is a positive integer.

Also,

- (1) if I1 and I1 + 1 are in $[1, NTAB1]$ then the indicated airspeed TABLE (I1) is less than the indicated airspeed TABLE (I1 + 1)
- (2) if I2 and I2 + 1 are in $[NTAB1 + 1, NN12]$ then the normal load factor TABLE (I2) is less than the normal load factor TABLE (I2 + 1)
- (3) if I3 and I3 + 1 are in $[NN12 + 1, NN13]$ then the altitude TABLE (I3), is less than the altitude TABLE (I3 + 1)
- (4) if I4 and I4 + 1 are in $[NN13 + 1, NN14]$ then the weight TABLE (I4) is less than the weight TABLE (I4 + 1)
- (5) if I1 is in $[1, NTAB1]$, I2 is in $[NTAB1 + 1, NN12]$, I3 is in $[NN12 + 1, NN13]$, I4 is in $[NN13 + 1, NN14]$

and n is in $[NN14 + 1, NF]$ and is equal to $NN14 + (I4 - NN13 - 1) \cdot NTAB3 \cdot NTAB2 \cdot NTAB1 + (I3 - NN12 - 1) \cdot NTAB2 \cdot NTAB1 + (I2 - NTAB1 - 1) \cdot NTAB1 + I1$ then the stress TABLE (n) is the stress that corresponds to the indicated airspeed TABLE ($I1$), the normal load factor TABLE ($I2$), the altitude TABLE ($I3$) and the weight TABLE ($I4$).

The positive integers $I1$, $I2$, $I3$, and $I4$ are determined as follows: A search is made for the integer i that will determine the smallest number TABLE (i) that equals or exceeds $VI(I, IR)$. If $i = 1$ satisfies this requirement then $I1$ is set equal to 2. If i is in $[2, NTAB1]$ then $I1$ is set equal to i . If no i can be found in $[2, NTAB1]$ then $I1$ is set equal to $NTAB1$. A search is made for the integer j that will determine the smallest number TABLE (j) that equals or exceeds $(NZ(J, JR))$. If $j = NTAB1 + 1$ then $I2$ is set equal to $NTAB1 + 2$. If j is in $[NTAB1 + 2, NN12]$ then $I2$ is set equal to j . If no j can be found to satisfy the requirement then $I2$ is set equal to $NN12$. Also, a search is made for the integer k that will determine the smallest number TABLE (k) that equals or exceeds $H(K, KR)$. If $k = NN12 + 1$ then $I3$ is set equal to $NN12 + 2$. If k is in $[NN12 + 2, NN13]$ then $I3$ is set equal to k . If no k can be found in $[NN12 + 2, NN13]$ then $I3$ is set equal to $NN13$. A final search is made for the integer m that will determine the smallest number TABLE (m) that equals or exceeds $W(M, MR)$. If $m = NN13 + 1$ then $I4$ is set equal to $NN13 + 2$. If m is in $[NN13 + 2, NN14]$ then $I4$ is set equal to m . If no m can be in $[NN13 + 2, NN14]$ then $I4$ is set equal to $NN14$.

The next step is to identify the integers required for the final calculations.

With

$$\begin{aligned} NP12 &= NTAB1 \cdot NTAB2 \\ NP13 &= NP12 \cdot NTAB3 \end{aligned}$$

these are:

$$\begin{aligned} N2222 &= NN14 + (I4 - NN13 - 1) \cdot NP13 + (I3 - NN12 - 1) \cdot \\ &\quad NP12 + (I2 - NTAB1 - 1) \cdot NTAB1 + I1 \\ N1222 &= N22 - 1 \\ N2122 &= N222 - NTAB1 \\ N1122 &= N2122 - 1 \\ N2212 &= N2222 - NP12 \end{aligned}$$

$N1212 = N2212 - 1$
 $N2112 = N2212 - NTAB1$
 $N1112 = N2112 - 1$
 $N2221 = N222 - NP13$
 $N1221 = N2221 - 1$
 $N2121 = N2221 - NTAB1$
 $N1121 = N2121 - 1$
 $N2211 = N2221 - NP12$
 $N1211 = N2211 - 1$
 $N2111 = N2211 - NTAB1$
 $N1111 = N2111 - 1$

Therefore, if

$$X1RAT = \frac{VI(I, IR) - TABLE(I1-1)}{TABLE(I1) - TABLE(I1-1)}$$

$$X2RAT = \frac{NZ(J, JR) - TABLE(I2-1)}{TABLE(I2) - TABLE(I2-1)}$$

$$X3RAT = \frac{H(K, KR) - TABLE(I3-1)}{TABLE(I3) - TABLE(I3-1)}$$

$$X4RAT = \frac{W(M, MR) - TABLE(I4-1)}{TABLE(I4) - TABLE(I4-1)}$$

then

$$\begin{aligned}
 AMP111 &= TABLE(N1111) + X1RAT(TABLE(N2111) - TABLE(N1111)) \\
 AMP211 &= TABLE(N1211) + X1RAT(TABLE(N2211) - TABLE(N1211)) \\
 AMP121 &= TABLE(N1121) + X1RAT(TABLE(N2121) - TABLE(N1121)) \\
 AMP221 &= TABLE(N1221) + X1RAT(TABLE(N2221) - TABLE(N1221)) \\
 AMP112 &= TABLE(N1112) + X1RAT(TABLE(N2112) - TABLE(N1112)) \\
 AMP212 &= TABLE(N1212) + X1RAT(TABLE(N2212) - TABLE(N1212)) \\
 AMP122 &= TABLE(N1122) + X1RAT(TABLE(N2122) - TABLE(N1122)) \\
 AMP222 &= TABLE(N1222) + X1RAT(TABLE(N2222) - TABLE(N1222)),
 \end{aligned}$$

$$AMP11 = AMP111 + X2RAT(AMP211 - AMP111)$$

$$AMP12 = AMP112 + X2RAT(AMP212 - AMP112)$$

$$AMP22 = AMP122 + X2RAT(AMP222 - AMP122),$$

$$\begin{aligned}
 AMP1 &= AMP11 + X3RAT(AMP21 - AMP11) \\
 AMP2 &= AMP12 + X3RAT(AMP22 - AMP12),
 \end{aligned}$$

$$\xi^a (K, J, K, M, IR, JR, KR, MR) = (AMP1 + X4RAT(AMP2 - AMP1)) \cdot FACTOR$$

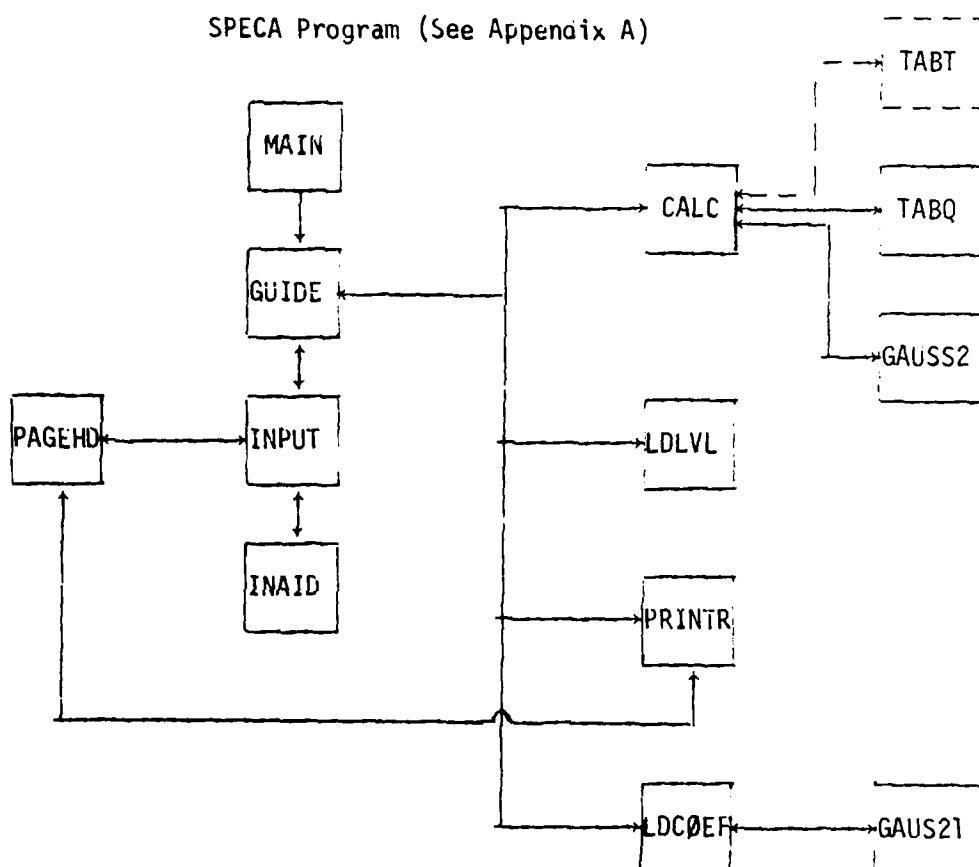
It is seen that the sixteen points on the ψ^a surface are reduced to eight points on the ξ^a surface by an interpolation on the indicated airspeed. The eight points are reduced to four points on the ξ^a surface by an interpolation on the normal load factor. Next, the

four points are reduced to two points on the Σ^3 surface by an interpolation on the altitude, and finally these two points are reduced to the desired stress by an interpolation on the weight.

Note that the number FACTOR is used to scale the calculation made in the table look up routine.

3 COMPUTER FLOW DIAGRAM AND PROGRAM

The computer routine was coded in FORTRAN Extended Language with the main program and subroutines arranged as follows:



MAIN - Main Program - Sets NZERO and NPSCT to zero and transfers program control to GUIDE

GUIDE - Subroutine - Initially zeros input and output numbers and after first case zeros output numbers before the calculations are performed. GUIDE, the main controlling subroutine, transfers control to INPUT, CALC, LDLVL, PRINTR, and LDCDEF in turn.

INPUT - Subroutine - Reads in all input data including the VGH histogram and the stress table. There are two formats for reading in floating point numbers and three formats for reading in fixed point numbers. The details of the data input are discussed later in this section.

INAID - Subroutine - Called by INPUT and has the purpose of writing out certain input data.

- (1) NRV1, NRV2, NRH, NRW
- (2) FACTOR
- (3) PSIL
- (4) AREAN
- (5) PS
- (6) Stress table
- (7) VGH histogram table
- (8) FVI, FNZ, FH, FW

Also, INAID sets NZERO=1 for control of data handling in GUIDE

PAGEHD - Subroutine - Writes out page heading including run identification, date and page number

CALC - Subroutine - Computes PPSI and PDPSI

LDLVL - Subroutine - Computes PSIL and F1AC

LDCDEF - Subroutine - Computer ALPHA

TABQ - Subroutine - Called from CALC to perform the interpolation discussed in Section IV, B, that computes the stress corresponding to a given indicated airspeed, normal load factor, altitude, and weight.

TABT - Subroutine - called from CALC as an alternate to TABQ for the interpolation to compute the stress corresponding to a given indicated airspeed, equivalent normal load factor, and altitude.

GAUSS2 - Subroutine - Called from CALC to solve the simultaneous equations that are required to pass second order equations through the points of PPS1 so that the differentiation for PDPS1 can be performed. The subroutine uses the Gauss-Jordan method for solving the sets of simultaneous equations.

GAUS21 - Subroutine - Called from LUCDEF and is used to solve the set of equations PLD(I) = PS(K,J) * ALPHA(J). This subroutine is identical to GAUSS2 except for a DIMENSION statement change.

PRINTR - Subroutine - Called from GUIDE to write out computed output data. In particular, PRINTR prints

- (1) PPS1
- (2) EXCEED
- (3) HOURS
- (4) PDPS1
- (5) PSILL, FRAC

4 EQUIVALENCE TABLES

The technique that has been used in coding this routine is to place all input and output numbers in blank common. All input and output floating point numbers are called parameters and are contained in P (dimensioned 10,000). All input and output fixed point numbers are called integers and are contained in NTEGER (dimensioned 100). To make the program more easily interpreted, EQUIVALENCE statements are used to provide the P and NTEGER numbers with more recognizable names. The SPECA program parameter and integer tables are given below.

PARAMETER EQUIVALENCE TABLE

P	Dimension	Term	P	Dimension	Term
1	(1)	FMN,FVI	1201	(100)	APDPSI(1,
2	(1)	FNZ	1300		APDPSI(100,
3	(1)	FH	1301	(100)	PSIL(1)
4	(1)	FW	1400		PSIL(100)
5	(1)	FACTØR	1401	(100)	FRAC(1)
6	(1)	HOURS	1500		FRAC(100)
.			1501	(100,25)	PLUS(1,1)
.			4000		PLDS(100,25)
.			4001	(25)	ALPHA(1)
.			4025		ALPHA(25)

P	Dimension	Term	P	Dimension	Term
100	(1)	NT	.		
101	(100)	PSIL(1)	.		
200		PSIL(100)	.		
201	(100)	AREAN(1)	5001	(25)	VII(1)
300		AREAN(100)	5025		VII(25)
301	(25,25)	PS(1,1)	5026	(25)	NZI(1)
925		PS(25,25)	5050		NZI(25)
.			5051	(25)	HI(1)
.			5075		HI(25)
.			5076	(25)	WI(1)
1001	(100)	PPSI(1)	5100	.	WI(25)
1100		PPSI(100)	.		
1101	(100)	PDPSI(1)	.		
1200		PDPSI(100)	6001	(100)	EXCEED(1)
			6100		EXCEED(100)

INTEGER EQUIVALENCE TABLE

NTEGER	Dimension	Term	NTEGER	Dimension	Term
1	(1)	IDENT	.		
2	.	NPF1	.		
3	.	NPF2	.		
4	.	NPF3	56	(2)	NTB41(1)
5		NPF4	57		NTB41(2)
6		NTI4	58	(2)	NTB42(1)
7		NTW4	59		NTB42(2)
8		MONTH	60	(2)	NTB42(1)
9		DAY	61		NTB43(2)
10		YEAR	62	(2)	NTB44(1)
11		NPSIL	63		NTB44(2)
12		NPSILL	64	(1)	NTB21
13		NPS	65	(1)	NTB22
14		NMORE			
15		NRMN			
16		NRNZ			
17		NRH			
18		NRW			
19					
20					
21		NTB			
.					
.					
49		NPAGE			

5 INPUT DATA

All of the input data described below is read into the program by means of the subroutine INPUT. INPUT is a general purpose subroutine for reading data from cards. For this program, the full capabilities of INPUT are not required and consequently there will be some zeros in the input that serve to bypass certain options.

The following deck arrangement is recommended:

14I5 Format

IDENT	NPF1	0	0	0	NT14	NTW4	MUNTH	DAY	YEAR	NPSI	NPSI	NPS	21
-------	------	---	---	---	------	------	-------	-----	------	------	------	-----	----

7I5 Format

NRVI	NRNZ	NRH	NRW	0	0	NIB
------	------	-----	-----	---	---	-----

72H Format

Run Description

72H Format

Run Description

3I5

1	6	1
---	---	---

6E10.3 Format

FVI	FNZ	FH	FW	FACTOR	HOURS
-----	-----	----	----	--------	-------

3I5 Format

101	100 +	NPSI	1
-----	-------	------	---

6E10.3 Format

PSIL(1) - PSIL(NPSIL)

3I5 Format

201	200 +	1
NPSILL		

6E10.3 Format

AREAN(1) - AREAN(NPSILL)

If NPS > 1 go to (a)

If NPS = 0 go to (b)

(a)

3I5 Format

301	300+	1
NPS		

6E10.3 Format

PS(1,1) - (PS(NPS,1)

3I5 Format

326	325 +	1
NPS		

6E10.3 Format

PS(1,2) - PS(NPS,2)

3I5 Format

351	350 +	1
NPS		

6E10.3 Format

PS(1,3) - PS(NPS,3)

3I5 Format

301 +	300 +	
25(NPS	(NPS-1)	1
-1)	·25+NPS	

6E10.3 Format

PS(1,NPS) - PS(NPS,NPS)

(b) If NTI4 > 0 go to (c) to read NI14 table(s). For the first run in a computer input the stress table and the VGH histogram table must be read. Subsequent runs may require no new tables (NTI4 = 0), one new table (NTI4 = 1), or two new tables (NTI4 = 2).

If NTI4 = 0 go to (g)

(c)

5I10 Format

1	NTAB1	NTAB2	NTAB3	NTAB4
---	-------	-------	-------	-------

(Stress table control cards)

6E10.3 Format

TABLE(1) - TABLE(NTAB1)
(indicated airspeeds for the stress table)

6E10.3 Format

TABLE(NTAB1+1) - TABLE(NN12)
(normal load factors for the stress table)

6E10.3 Format

TABLE(NN12+1) - TABLE(NN13)
(altitudes for the stress table)

If NTB = 1 go to (d)

If NTB = 2 go to (e)

(d)

6E10.3 Format

TABLE(NN13+1) - TABLE(NN14)
(weights for the stress table)

6E10.3 Format

TABLE(NN14+1) - TABLE(NF)
(stress amplitudes for the stress table)
(see Section 3.2 for ordering of these entries)

go to (f)

(e)

E10.3 Format

WTTB3
(ref. weight)

6E10.3 Format

TABLE(NN13+1) - TABLE(NF)
(stress amplitudes for the stress table)
(see Section 3.2 for ordering of these entries)

(f)

5I10 Format

2	NT421	NT422	NT423	NT424
---	-------	-------	-------	-------

(VGH histogram control cards)

6E10.3 Format

VII(1) - VII(NT421)
(indicated airspeeds for VGH histogram table)

NZI(1) - NZI(NT422)
(normal load factor for VGH histogram table)

H1(1) - H1(NT423)
(altitudes for VGH histogram table)

W1(1) - W1(NT424)
(weights for VGH histogram table)

$\gamma^a(VII(1), NZI(1), H1(1), W1(1))$ -
 $\gamma^a(VII(NT421), NZI(NT422), H1(NT423), W1(NT424))$
(load occurrences in VGH histogram table)
(see discussion below for ordering of these entries)

(g) END OF FILE

The first card contains 14 fixed point (integer) numbers arranged in 15 fields. These 14 entries in order on this card are

- (1) IDENT - run number
- (2) NPF1 = 3 if $N_p = 1$
= 3 + N_p if $N_p > 1$
- (3) 0
- (4) 0
- (5) 0
- (6) NT14 - the number of quadruple tables to be read (for this count the stress table and the VGH histogram table are each considered quadruple tables.)

- (7) NIW4 = 1 for print of quadruple tables
= 0 otherwise
- (8) MONTH - month in date for page heading
- (9) DAY - day in date for page heading
- (10) YEAR - year in date for page heading
- (11) NPS1L = N_{F_L}
- (12) NPS1LL = N_{F_L}
- (13) NPS - The number of control points if $N_p > 1$. NPS = 0
if $N_p = 1$
- (14) 21

The second card contains seven fixed point numbers arranged in 15 fields. In order these entries are

- (1) NRVI = $N_{V_i}^R$
- (2) NRNZ = $N_{n_z}^R$
- (3) NRH = N_h^R
- (4) NRW = N_w^R
- (5) 0
- (6) 0
- (7) NTB = 1 if the load occurrences in the VGH histogram depend on indicated airspeed, normal load factor, altitude, and weight.
NTB = 2 if the load occurrences in the VGH histogram depend on indicated airspeed, equivalent normal load factor, and altitude

The third and fourth cards contain a72H field each for the purpose of run description, etc.

The fifth card contains 1, 6, and 1 in 15 fields

The sixth card contains six floating point numbers arranged in E10.3 fields. These six numbers are placed in the following order:

- (1) FVI = $v_i(N_{V_i} + 1)$

- (2) FNZ = $n_z(N_{n_z} + 1)$
- (3) FH = $h(N_h + 1)$
- (4) FW = $w(N_w + 1)$
- (5) FACTOR - stress scaling factor
- (6) HOURS - number of hours of data in the VGH histogram

The seventh card contains the three fixed point numbers 101, 100 + NPSIL, 1 in order in 15 fields. NPSIL must not exceed 100.

The next card(s) contains(s) the numbers PSIL(1) through PSIL(NPSIL) in E10.3 fields, six numbers per card.

The next entry contains the fixed point numbers 201, 200 + NPSILL, 1 in order in 15 fields. NPSILL must not exceed 100.

Following this card the floating point numbers AREAN(1) through AREAN(NPSIL), arranged in E10.3 fields, six numbers per card, are entered.

If NPS = 0 then the PS matrix is omitted from the input deck.

If NPS = 1 then the PS matrix is placed next in the input deck. PS is dimensioned (25,25) and is equivalenced to P such that P(301) = PS(1,1). Therefore, it follows that P(300+NPS) = PS(NPS,1), P(326) = PS(1,2), and P(301+25(NPS-1)) = PS(1,NPS). Consequently the NPS blocks of data are read in as follows:

First block -

The first card contains the fixed point numbers 301, 300+NPS, 1 arranged in 15 fields.

The next entries are the floating point numbers PS(1,1) through PS(NPS,1) in E10.3 fields, six numbers per card.

Second block -

The first card contains the fixed point numbers 326, 325+NPS, 1 arranged in 15 fields.

The next entries are the floating point numbers PS(1,2) through PS(NPS,2) in E10.3 fields, six numbers per card.

.

.

.

Nr'Sth block -

The first card contains the fixed point numbers 301+ 25(NPS-1), 300+(NPS-1)(25) + NPS arranged in 15 fields.

The next entries are the floating point numbers PS(1,NFS) through PS(NPS,NFS) in E10.3 fields, six numbers per card.

The remaining entries are the stress table and the VGH histogram table. These entries are prepared as follows:

If I = 1 then the entry is the stress table where there are $NP = NTAB1 \cdot NTAB2 \cdot NTAB3 \cdot NTAB4$ points defined by NTAB1 indicated airspeeds, NTAB2 normal load factors, NTAB3 altitudes, NTAB4 weights. These points are entered as ordinates of the simple graph TABLE which was defined in paragraph 2 of this section.

The first card for the stress table contains five (5) fixed point numbers in 15 fields in the order

- (1) 1
- (2) NTAB1
- (3) NTAB2
- (4) NTAB3
- (5) NTAB4

The next card(s) contain(s) the indicated airspeeds (floating point numbers) TABLE(1) through TABLE(NTAB1) arranged in E10.6 fields, six numbers per card.

The next entries are the normal load factors TABLE(NTAB1 +1, NN12) (see paragraph 2 for definition of arguments) arranged in E10.3 fields six numbers per card.

Next, the card(s) that contain the altitudes TABLE(NN12+1) through TABLE(NN13) arranged in E10.3 fields, six numbers per card are entered in order.

The next entries depend on the number NTB.

If NTB = 1 the card(s) that contain(s) the weights TABLE(NN13+1) through TABLE(NN14) arranged in E10.3 fields, are entered with six numbers per card.

The next card(s) contain(s) the stresses TABLE(NN14+1) through TABLE(NF) arranged in E10.3 fields, six numbers per card. The ordering of the stresses in this entry is defined in paragraph 2 of this section.

If NTB = 2 a card is entered that contains the reference weight WTTB3 in an E10.3 field.

The next card(s) contain(s) the stresses TABLE(NN13+1) through TABLE(NF) arranged in E10.3 fields, six numbers per card. The number NF must not exceed 2000. The ordering of the stresses in this entry is defined in paragraph 2 of this section.
(Note that NTAB4 = 1 for this case.)

This completes the stress table

If I = 2 then the entry is the VGH histogram table where there are NP24 = NT421 · NT422 · NT423 · NT424 regions defined by NT421 indicated airspeed intervals, NT422 normal load factor intervals, NT423 altitude intervals, and NT424 weight intervals.

The first card for the VGH histogram table contains five fixed point numbers in I5 fields in the order

- (1) 2
- (2) NT421
- (3) NT422
- (4) NT423
- (5) NT424

Following this card are the card(s) with the indicated airspeeds (floating point numbers) VII(1) through VII(NT421) arranged in E10.3 fields, six numbers per card.

The next card(s) contain the normal load factors NZI(1) through NZI(NT422) arranged in E10.3 fields, six numbers per card.

Next are the card(s) that contain the altitudes HI(1) through HI(NT423) arranged in E10.3 fields, six numbers per card.

The weight entries WI(1) through WI(NT424) arranged in E10.3 field, six numbers per card, are next.

The final card(s) in the VGI histogram deck are the load occurrences in regions defined by the indicated airspeeds, normal load factors, altitudes, and weights. If i is in $[1, NP]$ then these entries are $\beta(VII(i), NZI(i), HI(i), WI(i))$ through $\beta(VII(NT421), NZI(NT422), HI(NT423), WI(NT424))$ arranged in E10.3 fields, six numbers per card. If i is in $[1, NT421]$, j is in $[1, NT422]$, k is in $[1, NT423]$, and m is in $[1, NT424]$ then the stress that corresponds to $VII(i)$, $NZI(j)$, $FI(k)$, $WI(m)$ is the $((m-1) \cdot NT421 + NT422 + NT423 + (k-1) \cdot NT421 + NT422 + (j-1) \cdot NT421 + i)$ th entry on these cards. The number $NT421 + NT422 + NT423 + NT424 + NT421 \cdot NT422 \cdot NT423 \cdot NT424$ must not exceed 2000.

6 SAMPLE PROBLEM

A sample run is presented for the purpose of acquainting the user with the input data cards and the output. The data used does not represent any particular aircraft or usage. It is assumed that two control points are sufficient in this case to define the full scale aircraft fatigue spectrum. The input cards are as follows:

100	5	0	0	0	2	1	3	30	1973	23	12	2	21
2	2	2	2	0	0	1							
CHECK OUT RUN FOR SPECA PROGRAM													
V G H DATA IN TABLE CONTROL POINT NUMBER 1 (REVISION 2) •													
1	6	1											
650.0	7.0		40000.0		36000.0		1.0		500.0				
101	123	1											
20000.0	22000.0		24000.0		26000.0		28000.0		30000.0				
32000.0	34000.0		36000.0		38000.0		40000.0		42000.0				
44000.0	46000.0		48000.0		50000.0		52000.0		54000.0				
56000.0	58000.0		60000.0		62000.0		64000.0						
201	212	1											
0.05	0.10		0.20		0.25		0.30		0.40				
0.50	0.60		0.70		0.80		0.90		0.95				
301	302	1											
20000.0	35000.0												

326 327 1
25000.0 30000.0

	1	3	3	3	3
300.0	500.0	600.0			
3.0	6.0	8.0			
5000.0	20000.0	35000.0			
25000.0	30000.0	35000.0			
20000.0	22000.0	25000.0	42000.0	43000.0	46000.0
55000.0	57000.0	58000.0	17000.0	18000.0	20000.0
32000.0	34000.0	35000.0	51000.0	53000.0	54000.0
15000.0	17000.0	18000.0	26000.0	28000.0	29000.0
41000.0	42000.0	44000.0	24000.0	26000.0	29000.0
46000.0	47000.0	50000.0	59000.0	61000.0	62000.0
21000.0	22000.0	24000.0	36000.0	38000.0	39000.0
55000.0	57000.0	58000.0	19000.0	21000.0	22000.0
30000.0	32000.0	33000.0	45000.0	46000.0	48000.0
27000.0	29000.0	32000.0	49000.0	50000.0	53000.0
62000.0	64000.0	65000.0	24000.0	25000.0	27000.0
39000.0	41000.0	42000.0	58000.0	60000.0	61000.0
22000.0	24000.0	25000.0	33000.0	35000.0	36000.0
48000.0	49000.0	51000.0			

	2	3	3	3	3
350.0	450.0	550.0			
4.0	5.0	6.0			
10000.0	20000.0	30000.0			
30000.0	32000.0	34000.0			
500.0	1000.0	600.0	1000.0	1100.0	600.0
700.0	770.0	7700.0	100.0	4000.0	600.0
1000.0	100.0	1000.0	700.0	2000.0	600.0
6000.0	1000.0	4000.0	600.0	6000.0	1000.0
700.0	1000.0	6000.0	3000.0	600.0	700.0
1000.0	2000.0	500.0	4000.0	700.0	1000.0
500.0	4000.0	6000.0	700.0	7000.0	7700.0
4000.0	2000.0	700.0	500.0	3000.0	500.0
1000.0	600.0	3000.0	1000.0	500.0	5000.0
700.0	4000.0	600.0	3000.0	4000.0	400.0
1000.0	100.0	500.0	5000.0	5500.0	4000.0
500.0	1000.0	700.0	500.0	5000.0	3000.0
600.0	6000.0	3000.0	2000.0	4000.0	3000.0
1000.0	2000.0	200.0			

100 0 0 0 1 1 8 30 1973 23 12 2 21

2 2 2 0 0 1

CHECK OUT FOR SPECIA PROGRAM

V G H DATA IN TABLE CONTROL POINT NUMBER 2

1 3 3 3 3

300.0 500.0 600.0

3.0	6.0	8.0			
5000.0	20000.0	35000.0			
25000.0	30000.0	35000.0			
10000.0	20000.0	24000.0	36000.0	39000.0	40000.0
45000.0	50000.0	53000.0	17000.0	18000.0	20000.0
25000.0	27000.0	30000.0	51000.0	53000.0	54000.0
15000.0	17000.0	18000.0	26000.0	28000.0	29000.0
32000.0	34000.0	36000.0	25000.0	26000.0	27000.0
42000.0	43000.0	44000.0	55000.0	56000.0	57000.0
21000.0	22000.0	24000.0	36000.0	38000.0	39000.0
55000.0	57000.0	58000.0	19000.0	21000.0	22000.0
30000.0	32000.0	33000.0	45000.0	46000.0	48000.0
27000.0	29000.0	32000.0	49000.0	50000.0	53000.0
62000.0	64000.0	65000.0	24000.0	25000.0	27000.0
39000.0	41000.0	42000.0	58000.0	60000.0	61000.0
22000.0	24000.0	25000.0	33000.0	35000.0	36000.0
48000.0	49000.0	51000.0			

Based on this input the following output listing was obtained.

RUN NO 100 DATE 6/20/1971 PAGE NO 1

CHECK OUT RUN FOR SPECIA PROGRAM
VGM DATA IN TABLE CONTROL POINT NUMBER 1 (REVISION 2)

WISCONSIN SUBDIVISIONS

WIS1 2
WIS2 2
WIS3 2
WIS4 2

LOAD MAGNIFICATION FACTOR = 1,0000

INTERVAL LOAD LEVELS FOR INTEGRATION OF JOINT DENSITY FUNCTION

1	2.0000E+04	2	2.2000E+04	3	2.4000E+04	4	2.6000E+04
5	2.5000E+04	6	3.0000E+04	7	3.2000E+04	8	3.4000E+04
9	3.5000E+04	10	3.8000E+04	11	4.0000E+04	12	4.2000E+04
13	4.5000E+04	14	4.8000E+04	15	4.9000E+04	16	5.0000E+04
17	5.5000E+04	18	5.4914E+04	19	5.4000E+04	20	5.4001E+04
21	6.0000E+04	22	6.2000E+04	23	6.4000E+04	24	0.

CUMULATIVE AREA'S OF LOAD PROBABILITY DENSITY FUNCTION

1	2.00 001 02	2	1.000000E-01	3	2.000000E-01	4	2.500000E-01
5	3.00 001 01	6	4.000000E-01	7	5.000000E-01	8	6.000000E-01
9	4.00 001 01	10	5.000000E-01	11	9.000000E-01	12	9.500000E-01

PUN NO 100 DATE 8/10/1973 PAGE NO 2

QUADRUPLE TABLE NO. 1

PRT VS VT, N7, M1, M		PRT VS VT, N7, M1, M		PRT VS VT, N7, M1, M		PRT VS VT, N7, M1, M	
300.0	400.0	600.0					
3000.0	N7	6,000.0					
3,000.0	H	6,000.0	A,000.0				
500.0		2000.0		3500.0			
2500.0		3000.0		3500.0			
20010.	PST						
21100.		25000.		43000.			
14200.		35100.		51000.			
32030.		46100.		51000.			
41000.		26100.		21000.			
21000.		36000.		39000.			
27000.		26100.		65000.			
31000.		31100.		46000.			
36000.		45000.		46000.			
67030.		46100.		25000.			
22030.		24100.		27000.			
		25000.		30000.			
		31000.		36000.			
		31000.		41000.			
				44000.			

RUN NO. 100 DATE 8/10/1973 PAGE NO. 3

DISRUPTIF TABLE NO. 2

MISTY VS VILE, 2-M, H

VI 450.0 540.0

FN7 400.0 540.0

FN10 5,000.0 6,000.0

FN12 20000.0 30000.

FN14 30000.0 35000.

FN16 35000.0 40000.

FN18 40000.0 45000.

FN20 45000.0 50000.

FN22 50000.0 55000.

FN24 55000.0 60000.

FN26 60000.0 65000.

FN28 65000.0 70000.

FN30 70000.0 75000.

FN32 75000.0 80000.

FN34 80000.0 85000.

FN36 85000.0 90000.

FN38 90000.0 95000.

FN40 95000.0 100000.

FN42 100000.0 105000.

FN44 105000.0 110000.

FN46 110000.0 115000.

FN48 115000.0 120000.

FN50 120000.0 125000.

FN52 125000.0 130000.

FN54 130000.0 135000.

FN56 135000.0 140000.

FN58 140000.0 145000.

FN60 145000.0 150000.

FN62 150000.0 155000.

FN64 155000.0 160000.

FN66 160000.0 165000.

FN68 165000.0 170000.

FN70 170000.0 175000.

FN72 175000.0 180000.

FN74 180000.0 185000.

FN76 185000.0 190000.

FN78 190000.0 195000.

FN80 195000.0 200000.

FN82 200000.0 205000.

FN84 205000.0 210000.

FN86 210000.0 215000.

FN88 215000.0 220000.

FN90 220000.0 225000.

FN92 225000.0 230000.

FN94 230000.0 235000.

FN96 235000.0 240000.

FN98 240000.0 245000.

FN100 245000.0 250000.

FN102 250000.0 255000.

FN104 255000.0 260000.

FN106 260000.0 265000.

FN108 265000.0 270000.

FN110 270000.0 275000.

FN112 275000.0 280000.

FN114 280000.0 285000.

FN116 285000.0 290000.

FN118 290000.0 295000.

FN120 295000.0 300000.

FN122 300000.0 305000.

FN124 305000.0 310000.

FN126 310000.0 315000.

FN128 315000.0 320000.

FN130 320000.0 325000.

FN132 325000.0 330000.

FN134 330000.0 335000.

FN136 335000.0 340000.

FN138 340000.0 345000.

FN140 345000.0 350000.

LAST ASSESSAS IN TABLE 2

VI = 750100+93

FN7 = 7931325+91

FN10 = 460100+95

FN12 = 7691305+95

RUN NO 100 DATE 8/30/1973 PAGE NO 4

INTERNAL LOAD CUMULATIVE PROBABILITY FUNCTION					
LOAD	CUM PROB	LOAD	CUM PROB	LOAD	CUM PROB
2.46930E+04	1.00000E+00	2.200000E+04	1.00000E+00	2.400000E+04	1.00000E+00
2.46930E+04	9.41014E-01	2.400000E+04	9.30656E-01	3.00000E+04	8.31126E-01
2.46930E+04	8.40719E-01	2.400000E+04	5.440377E-01	3.60000E+04	5.22759E-01
3.20033E+04	6.80719E-01	3.400000E+04	4.000000E+04	4.200000E+04	1.738643E-01
3.20033E+04	3.22178E-01	4.000000E+04	2.443942E-01	4.800000E+04	3.48610E-02
4.40300E+04	1.14117E-01	4.600000E+04	7.876544E-02	5.200000E+04	5.400000E-02
4.40300E+04	1.74117E-01	5.200000E+04	1.443471E-01	5.800000E+04	1.407717E-01
5.00000E+04	0.	5.200000E+04	0.	6.000000E+04	0.
6.20033E+04	0.	6.400000E+04	0.	6.400000E+04	0.

RUN NO. 100

DATE 8/30/1973

PAGE NO. 5

CUMULATIVE NUMBER OF EXCEEDANCES PER 1000 HRS		LOAD	EXCEEDANCES	LOAD	EXCEEDANCES	LOAD	EXCEEDANCES
2.00000E+04	3.47740E+05	2.00000E+04	3.45740E+05	2.40000E+04	3.45740E+05	2.80000E+04	3.45740E+05
2.60000E+04	3.31775E+05	2.40000E+04	3.21750E+05	2.80000E+04	3.17522E+05	3.20000E+04	3.17522E+05
3.20000E+04	2.31750E+05	3.40000E+04	1.81025E+05	3.80000E+04	1.61655E+05	4.20000E+04	1.61655E+05
3.80000E+04	1.11390E+05	4.00000E+04	8.47750E+04	4.40000E+04	6.47750E+04	4.80000E+04	6.47750E+04
4.40000E+04	4.04250E+04	4.60000E+04	2.723250E+04	5.00000E+04	6.37500E+02	5.40000E+04	6.37500E+02
5.00000E+04	6.16250E+03	5.10000E+04	0.	5.50000E+04	0.	5.90000E+04	0.
5.60000E+04	0.	5.70000E+04	0.	6.10000E+04	0.	6.50000E+04	0.
6.20000E+04	0.	6.40000E+04	0.	6.80000E+04	0.	7.20000E+04	0.

BASED ON 505.00 HOURS

BUN N# 100 DATE 8/10/1973 PAGE NO. 6

INTERNAL LOAD PENALTY FUNCTION

LOAD	PCN	DEF	LOAD	PCN	DEF	LOAD	PCN	DEF
2.000000E+04	1.95772AF-14	2.200000E+04	1.562652E-19	2.400000E+04	6.745227E-06			
2.43713E+04	1.731640E-15	2.400000E+04	3.716743E-05	3.000000E+04	6.114612E-05			
1.203700E+04	7.186190E-05	1.400000E+04	6.54201E-05	3.600000E+04	5.546919E-05			
1.030291E+04	6.460541E-05	4.000000CF+04	3.777456E-05	4.200000E+04	3.155101E-05			
6.460100E+04	2.71911E-05	4.600000E+04	1.974104E-05	4.900000E+04	1.523546E-05			
6.000000E+04	0.7200057F-05	5.200000E+04	4.410029E-05	5.400000E+04	4.69467AF-07			
5.601100E+04	8.710240E-05	5.800000E+04	0.	6.000000E+04	0.			
6.700000E+04	0.	6.400000E+04	0.	6.000000E+04	0.			

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CRYSTIC LOADING FRACTIONS

LOAD	FRACTION	LOAD	FRACTION	LOAD	FRACTION
2.76294E+04	7.50000E-02	2.672792E+04	7.50000E-02	3.643048E+04	7.50000E-02
3.11111E+04	5.00000E-02	3.10050E+04	7.50000E-02	3.317683E+04	1.00000E-01
3.464790E+04	3.13000E-01	3.641536E+04	1.00000E-01	3.858915E+04	1.00000E-01
6.120775E+04	1.00000E-01	6.492567E+04	7.50000E-02	6.733516E+04	7.50000E-02
TOTAL LOAD CYCL S = 172870.					

PUN N7 100 DATE 8/18/1973 PAGE NO. 8

CHECK OUT FOR OPERA PROGRAM
VGM DATA IN FILE CONTROL POINT NUMBER 2

WICHTIGER SURVEY POINTS
NOV1 = 2
NOV2 = 2
NOV3 = 2
NOV4 = 2

LOAN MAGNIFICATION FACTOR = 1.0000

INTERNAL LOAD LEVELS FOR INTEGRATION OF JOINT DENSITY FUNCTION

1	2.00E+04	2	2.20000E+04	3	2.40000E+04	4	2.60000E+04
5	2.00E+04	6	3.00000E+04	7	3.20000E+04	8	3.40000E+04
9	3.00E+04	10	3.20000E+04	11	3.40000E+04	12	3.60000E+04
13	4.00E+04	14	4.80000E+04	15	4.80000E+04	16	5.00000E+04
17	5.20000E+04	18	5.40000E+04	19	5.60000E+04	20	5.80000E+04
21	6.00E+04	22	6.20000E+04	23	6.40000E+04	24	6.

CUMULATIVE AREAS OF LOAN PROBABILITY DENSITY FUNCTION

1	5.00000E-01	2	1.00000E-01	3	2.00000E-01	4	2.50000E-01
5	1.00000E-01	6	6.00000E-01	7	5.00000E-01	8	6.00000E-01
9	7.00000E-01	10	6.00000E-01	11	9.00000E-01	12	9.50000E-01

PAGE NO 6

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PUN NO	106	DATE	07/30/1973	PAGE NO	10
QUADRUPLE TARIFF NO. 1					
PST VS VI, W7, W8, W9					
VI					
100.0	N7	009.0	600.0		
3.0000	N	6.0000	8.0000		
500.0	N	2000.0	3500.0		
2000.0	N	10000.0	35000.0		
PST					
100.0		200.0	24000.	19000.	50000.
24000.		27000.	51000.	54000.	10000.
36000.		36000.	93000.	150000.	16000.
120.0		16000.	25000.	27000.	26000.
210.0		36000.	26000.	42000.	40000.
210.0		24100.	36000.	39000.	50000.
100.0		24100.	36000.	50000.	50000.
100.0		17100.	45000.	46000.	27000.
650.0		65000.	25000.	27000.	32000.
210.0		24100.	31000.	39000.	40000.
210.0		24100.	31000.	36000.	42000.

RIN NO. 100 DATE 6/30/1971 PAGE NO. 11

QUADRUPLE TABLE NO. 2

WISTJ VS V10, +2, H, V

VT 150.0 450.0 550.0

4.0000 5.0000 6.0010

10000. 20000. 30000.

50000. 100000. 150000.

500. 1000. 600.

1000. 1500. 2000.

2000. 2500. 3000.

3000. 4000. 5000.

4000. 5000. 6000.

5000. 6000. 7000.

7000. 8000. 9000.

8000. 9000. 10000.

10000. 11000. 12000.

12000. 13000. 14000.

13000. 14000. 15000.

14000. 15000. 16000.

15000. 16000. 17000.

16000. 17000. 18000.

17000. 18000. 19000.

18000. 19000. 20000.

19000. 20000. 21000.

20000. 21000. 22000.

21000. 22000. 23000.

22000. 23000. 24000.

23000. 24000. 25000.

24000. 25000. 26000.

25000. 26000. 27000.

26000. 27000. 28000.

27000. 28000. 29000.

28000. 29000. 30000.

29000. 30000. 31000.

30000. 31000. 32000.

31000. 32000. 33000.

32000. 33000. 34000.

33000. 34000. 35000.

34000. 35000. 36000.

35000. 36000. 37000.

36000. 37000. 38000.

37000. 38000. 39000.

LAST AND CLASSIC IN TABLE 2

VT = 0.5000000000000000

FPV = 70.00000000000000

FP = 40.00000000000000

FW = 0.5000000000000000

FW = 0.5000000000000000

12 PAGE NO. 10/10/1973 DATE 100 PIN NO. FINANCIAL LOAN CUMULATIVE PREEMITTENT FUNCTION LOAD CUM PROB

INTERPOLATION POINT	LOAN CUMULATIVE PROBABILITY	CUM PROB
2.000000E+04	1.000000E+00	2.000000E+00
2.666667E+04	9.111111E-01	2.666667E+00
3.333333E+04	8.222222E-01	3.333333E+00
4.000000E+04	7.333333E-01	4.000000E+00
4.666667E+04	6.444444E-01	4.666667E+00
5.333333E+04	5.555556E-01	5.333333E+00
6.000000E+04	4.666667E-01	6.000000E+00
6.666667E+04	3.777778E-01	6.666667E+00
7.333333E+04	2.888889E-01	7.333333E+00
8.000000E+04	2.000000E-01	8.000000E+00
8.666667E+04	1.111111E-01	8.666667E+00
9.333333E+04	2.222222E-01	9.333333E+00
1.000000E+05	3.333333E-01	1.000000E+01

```

LOAD    CUM PROB
2.746000E+01 1.000000E+00
3.000000E+01 9.314545E-01
3.500000E+01 6.22315E-01
4.000000E+01 1.47774E-01
4.500000E+01 2.727794E-01
5.000000E+01 2.000000E+00
6.000000E+01 1.000000E+00

```

RUN NO 100 DATE 8/30/1973 PAGE NO 13

CUMULATIVE NUMBER OF EXCEEDANCES PEP 1000 MPS			
LOAD	EXCEEDANCES	LOAD	
2.000000E+04	1.5910E+05	2.000000E+04	3.537E+05
2.400000E+04	3.19177E+05	2.400000E+04	3.21745E+05
2.800000E+04	2.10377E+05	2.800000E+04	1.81165E+05
3.200000E+04	1.000000E+04	3.200000E+04	1.43312E+05
3.600000E+04	1.000000E+04	3.600000E+04	1.500000E+05
4.000000E+04	1.000000E+04	4.000000E+04	6.27650E+04
4.400000E+04	1.000000E+04	4.400000E+04	4.000000E+04
4.800000E+04	1.000000E+04	4.800000E+04	2.26125E+04
5.200000E+04	1.000000E+04	5.200000E+04	2.62500E+02
5.600000E+04	1.000000E+04	5.600000E+04	6.25000E+01
6.000000E+04	0.	6.000000E+04	0.
6.400000E+04	0.	6.400000E+04	0.
6.200000E+04	0.	6.200000E+04	0.

BASED ON 500,000 HOURS

RUN NO. 100 DATE 8/10/1971 PAGE NO. 16

INTERNAL LOAD PROBABILITY DENSITY FUNCTION		LOAD	PROB. OF N	LOAD	PROB. OF N
PROB. OF N	LOAD	6.562652E-9	2.400000E-04	6.7465227E-05	
2.000000E-04	1.451924E-18	2.000000E-04	3.739572E-05	3.000000E-04	6.172257E-05
2.501000E-04	1.711600E-05	2.000000E-04	5.517117E-05	3.500000E-04	5.517117E-05
3.200000E-04	7.255556E-05	1.500000E-04	6.586095E-05	4.200000E-04	3.272774E-05
3.700000E-04	9.000000E-05	4.000000E-04	3.197152E-05	4.200000E-04	2.000000E-05
4.200000E-04	6.5220071E-05	4.601000E-04	2.016147E-05	4.600000E-04	1.505774E-05
4.400000E-04	2.574041E-05	5.000000E-04	1.130442E-06	5.400000E-04	1.494135E-02
5.000000E-04	6.767194E-06	5.000000E-04	0.	6.000000E-04	0.
5.600000E-04	4.519292E-04	6.400000E-04	0.		
6.200000E-04	0.				

15
DARF N7
DARF N7
DARF N7
DARF N7
DARF N7

CYCLIC LOADING FRACTIONS		LOAD	FRACTION	LOAD	FRACTION
LOAD	0.400000E+02	2.677356E+04	7.500000E-02	1.041954E+04	7.500000E-02
2.702056E+04	2.677356E+02	2.677356E+04	7.500000E-02	1.041954E+04	1.041954E+04
1.901013E+04	5.300000E+02	1.637752E+04	7.500000E-02	1.313191E+04	1.041954E+04
1.637752E+04	1.300000E+02	1.637752E+04	1.041954E+04	1.454539E+04	1.041954E+04
1.010645E+04	1.000000E+02	4.637752E+04	7.500000E-02	4.637752E+04	7.500000E-02
TOTAL LOADS = 1728700					

SECTION IV

EXAMPLE PROBLEM - F-4 STRESS SPECTRUM FOR POSITIVE LOAD FACTORS

The data base for this problem is four quarters of VGH data starting with the second quarter of 1972 and finishing with the first quarter of 1973. The VGH histogram intervals for these data are the following:

Indicated airspeed (knots)
150, 200, 250, 300, 350, 400, 450, 500, 550, 625, and 700

Normal load factor (equivalent)
1.4, 1.8, 2.2, 2.6, 3.0, 3.8, 4.6, 5.4, 6.6, 7.8, and 9.0

Altitude (feet)
0, 1000, 2000, 5000, 10,000, 15,000, 20,000, 30,000,
40,000, and 50,000

Weight (pounds)
37,500 (reference weight)

The stress table was set up with the following indicated airspeed, normal load factor, altitude, and weight combinations:

Indicated airspeed (knots)
175, 225, 275, 325, 375, 425, 475, 525, 575, and 625

Normal load factor
2.4, 2.8, 3.4, 4.2, 5.0, 6.0, 7.2, and 8.9

Altitude (feet)
500, 1500, 3500, 7500, 12500, 17500, 25000, and 35000

Weight (pounds)
37,500

The VGH histogram table was made up using all of the available data for the air-to-air and air-to-ground operations for the four quarters without distinguishing the various F-4 models except that only the unslatted configurations were considered. The numbers of hours of data in each category and their corresponding numbers of positive and negative load occurrences are shown in Table 1.

The number of stress exceedances per 1000 hours for load reference station (LRS) 180, defined in Figure 1 is shown in Figure 2 through Figure 7. Figure 2 through Figure 5 shows the variation from quarter to quarter of the VGH data. The stress exceedance graphs appear to show a small degree of scatter except for the SEA air-to-air first quarter where there was an overt change in the mission although it was still categorized as air-to-air. The four quarters of data are combined in Figures 6 and 7 to show the differences between the CONUS and SEA in the air-to-air operation and the air-to-ground operation.

SECTION V CONCLUSIONS

The procedure described in this report can eliminate much of the uncertainty that can occur in the derivation of the maneuver load stress spectrum. For new aircraft an estimate must be made of the VGH histogram to obtain the spectrum. This estimate can be updated during Task V of ASIP to derive a better estimate for the operational life of the fleet. This procedure can be immediately applied to fleet tracking by computing the conditional probability of exceeding a stress level given the normal load factor.

The application to full scale aircraft testing makes use of the assumption that the stress is matched at a specified number of control points by a linear combination of the same number of balanced loading conditions. This technique is believed to be more accurate than the usual process of a damage match at the specified control points in that the troublesome damage calculation is eliminated. The stress spectra at points other than control points are presumed to be matched satisfactorily by using representative loading conditions. It is, of course, theoretically better to use all points of the sky that occur in the VGH histogram. This, however, may be impractical due to test equipment limitations.

The procedure as applied to the F-4 fleet indicates that in general the stress spectra do not show significant changes from quarter to quarter. Also, when an operational change is made the method will reflect that change. When CONUS and SEA data are compared there appears to be a reasonably good correlation between the spectra generated in training and the spectra generated in combat.

TABLE 1. F-4 VGH DATA SUMMARY

PERIOD	TYPE	HOURS	+ COUNTS	- COUNTS	TOTAL COUNTS
2Q 72	CONUS AA	196.87	13981	4541	18522
2Q 72	SEA AA	65.84	4047	662	4709
2Q 72	CONUS AG	251.70	30723	9432	40155
2Q 72	SEA AG	1248.94	93027	13258	106285
3Q 72	CONUS AA	290.22	17470	5259	22729
3Q 72	SEA AA	393.26	30842	6366	37208
3Q 72	CONUS AG	469.64	38968	9934	48902
3Q 72	SEA AG	802.74	66446	12485	78931
4Q 72	CONUS AA	184.92	9404	3138	12542
4Q 72	SEA AA	164.35	7862	1933	9795
4Q 72	CONUS AG	89.16	5959	1265	7224
4Q 72	SEA AA	502.09	28254	4819	33073
1Q 73	CONUS AA	123.18	7983	2231	10214
1Q 73	SEA AA	133.96	6100	1358	7458
1Q 73	CONUS AG	194.38	17828	4001	21829
1Q 73	SEA AG	933.87	42342	8229	50571

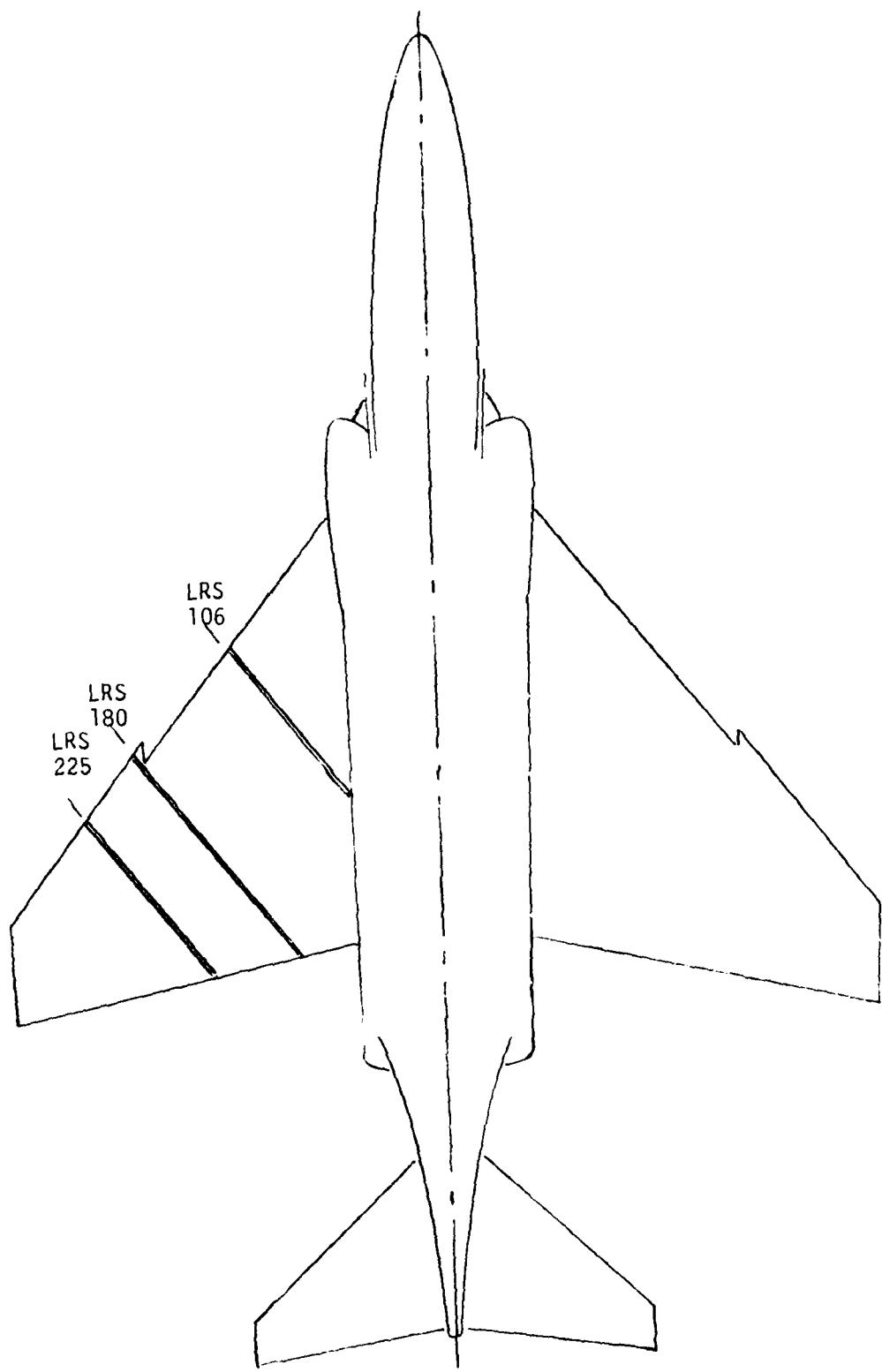


Figure 1. F-4 Wing Load Reference Station Locations

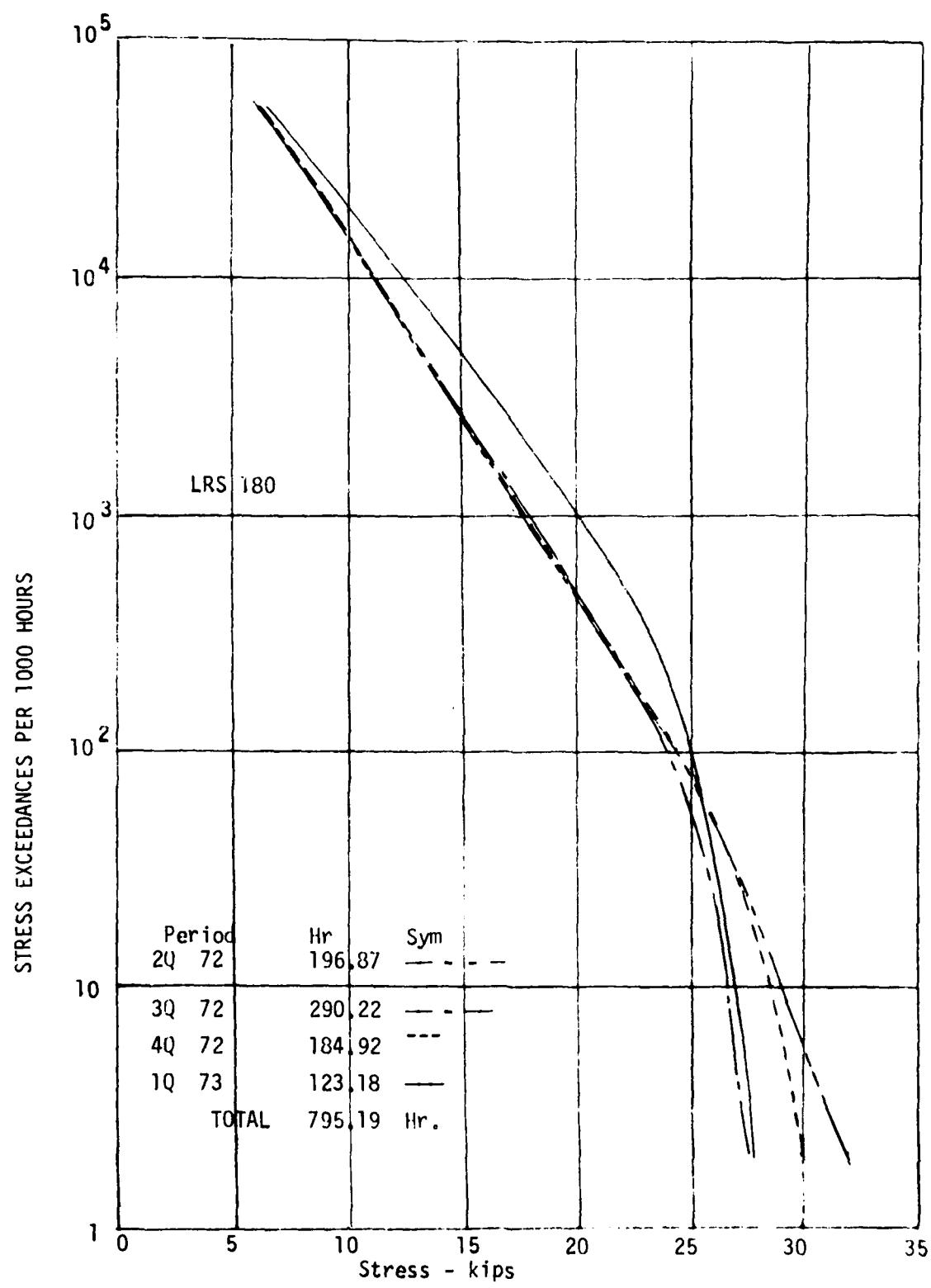


Figure 2. F-4 Spectra - CONUS Air-to-Air (All Models)

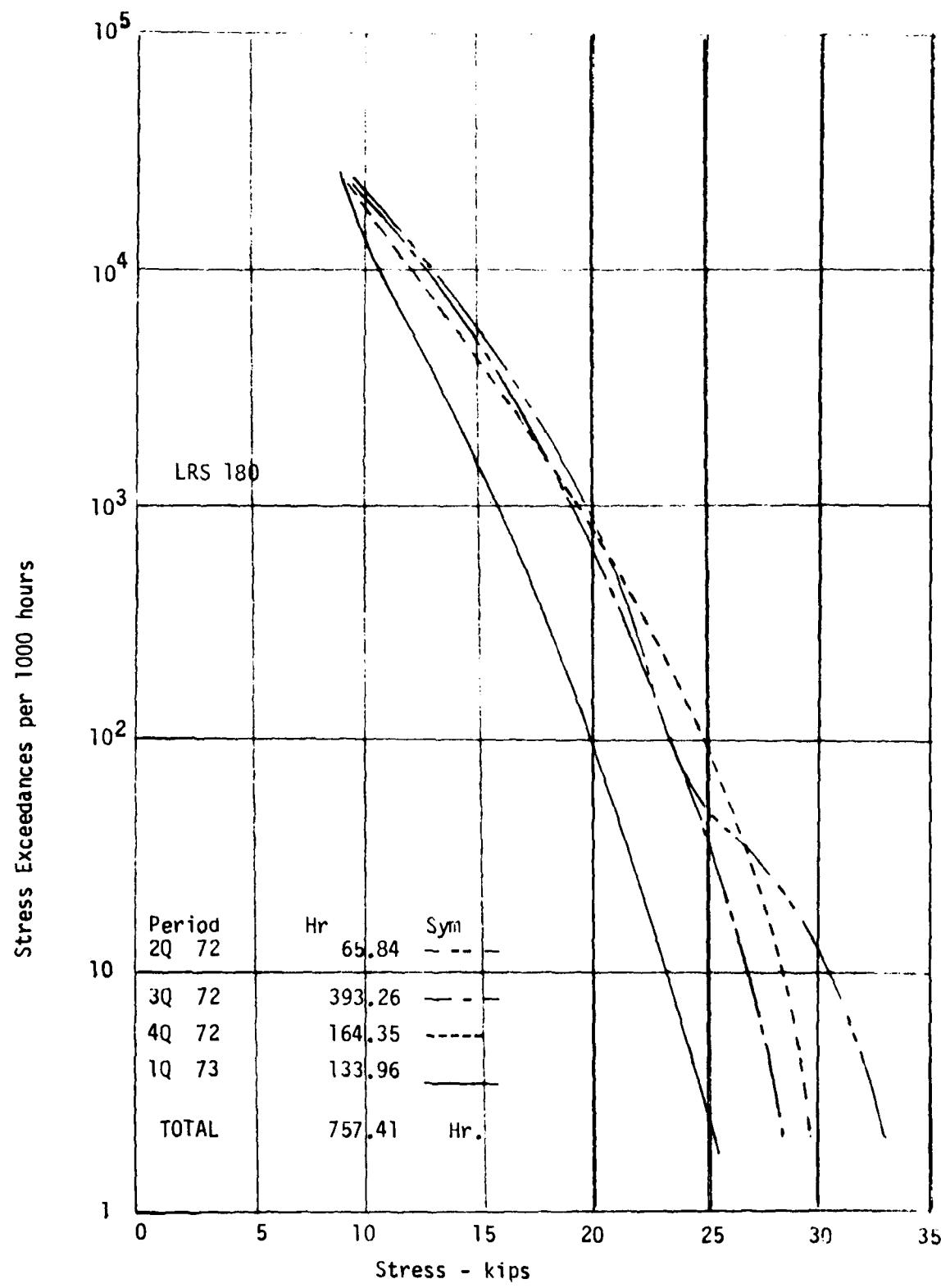


Figure 3. F-4 Spectra - SEA Air-to-Air (All Models)

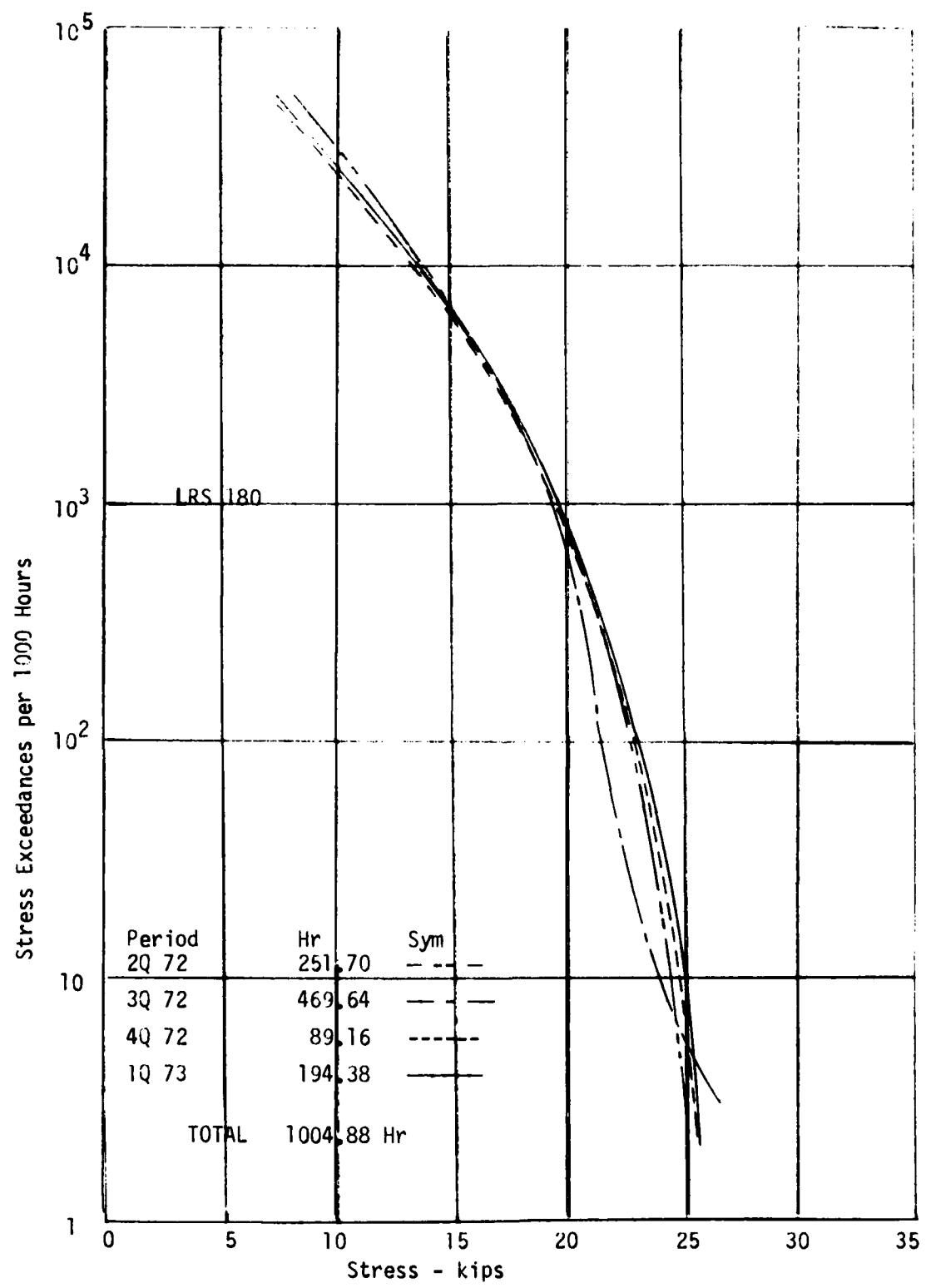


Figure 4. F-4 Spectra - CONUS Air-to-Ground (All Models)

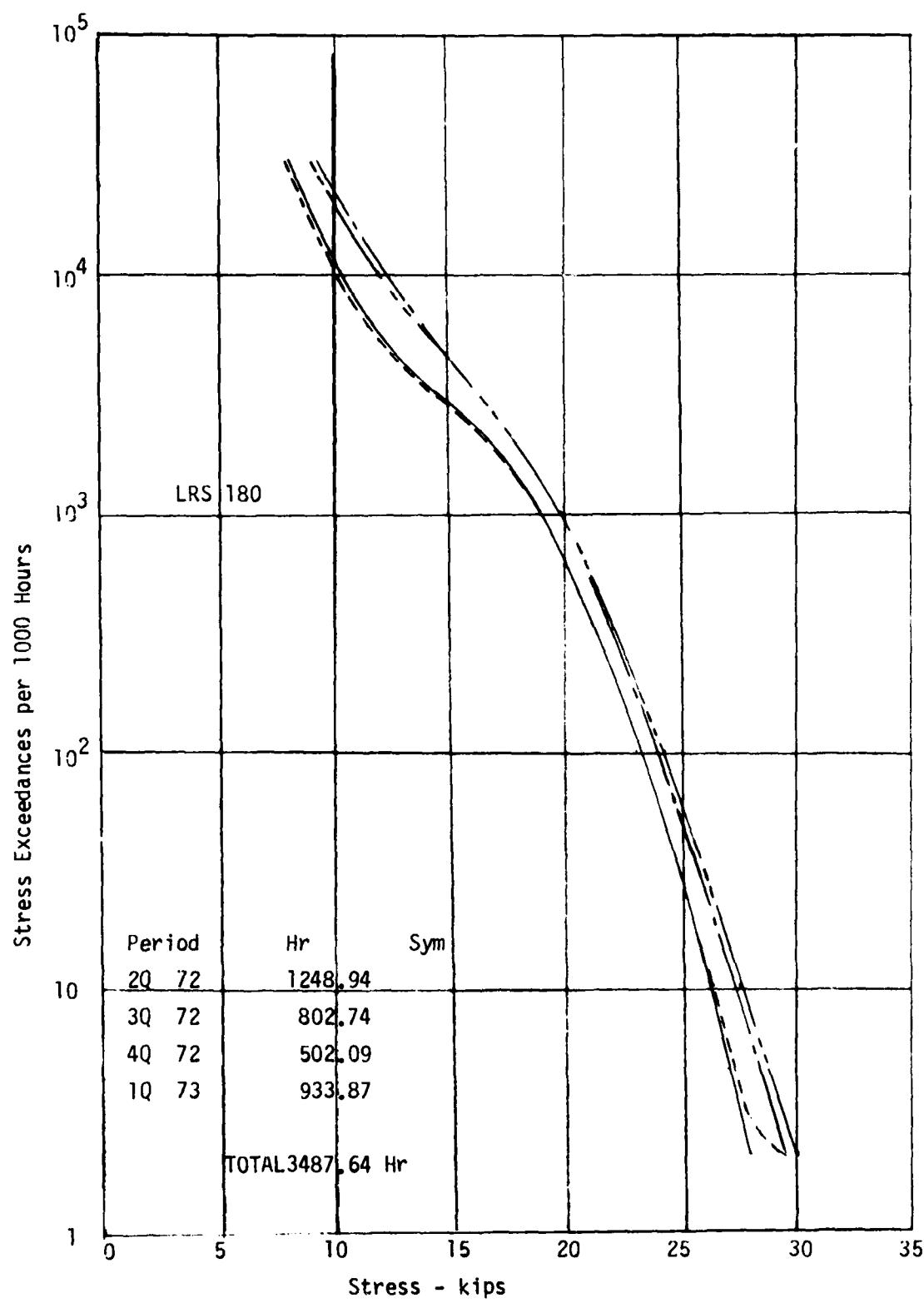


Figure 5. F-1 Spectra - SEA Air-to-Ground (All Models)

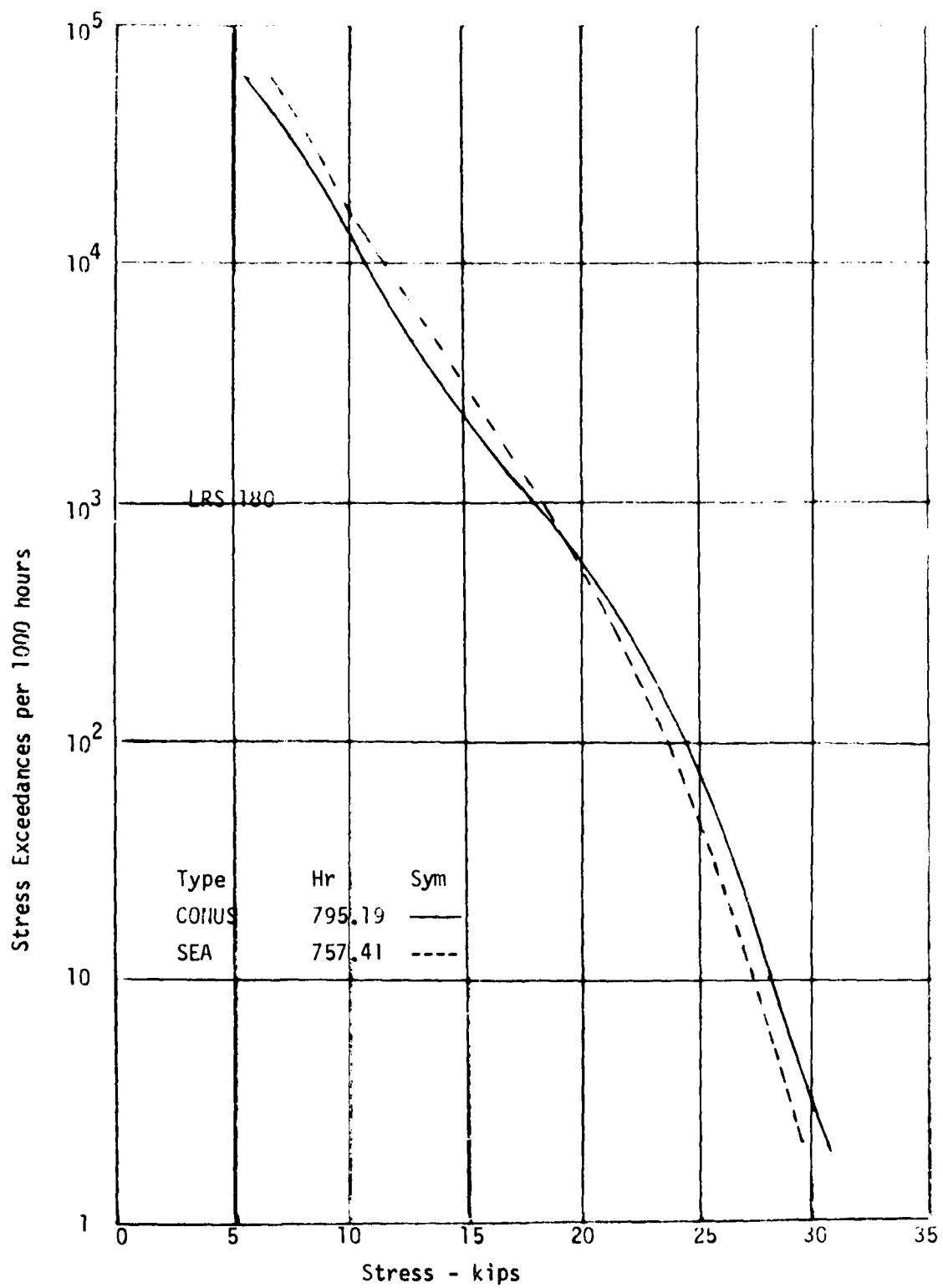


Figure 6. F-4 Spectra - Air-to-Air (All Models)
for One Year of VGH Data

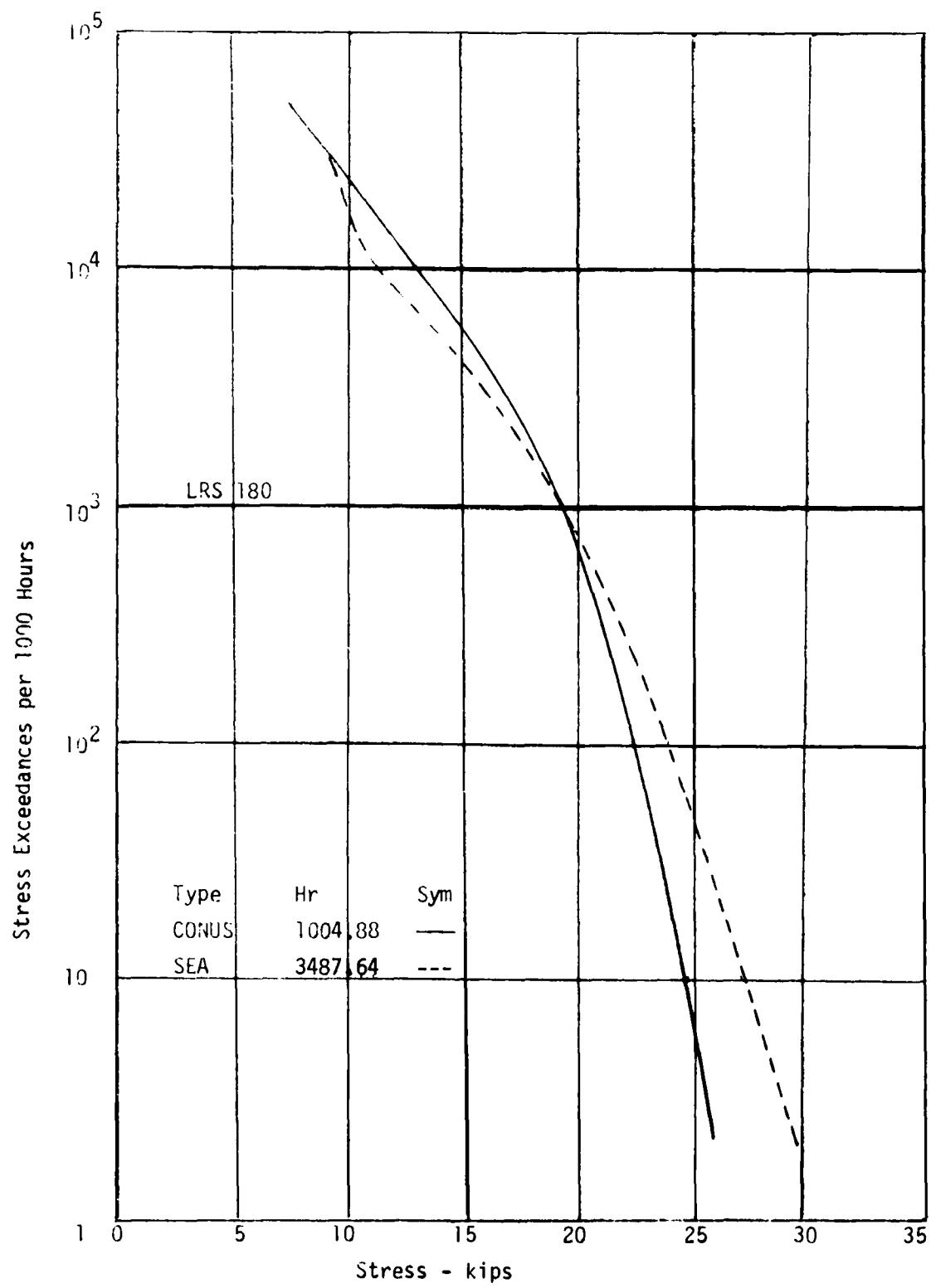


Figure 7. F-4 Spectra - Air-to-Ground (All Models)
for One Year of VGH Data

APPENDIX - SPECA PROGRAM LISTING

The listing given below is a FORTRAN extended language routine. This listing contains all of the statements for the version described in the Introduction of this report. Section 3.3 gives a brief description of each of the subroutines in this listing.

```
PROGRAM SPICA(INPUT,OUTPUT,TAPES,INPUT,OUTPUT,INTERNAL LOAD PROBABILITY
C      PROGRAM FOR COMPUTING AIRCRAFT INTERNAL LOAD PROBABILITY
C      DENSITY FUNCTIONS
C      REVISION 2
      COMMON PT100001, NIFER(100), TARI(2000,2),
      EQUIVALENCE (NIFER(100), NZERO), (TARI(2000,2),
      NZERO = 0
      NPCT = 0
      CALL GUDI
      GO TO 10
      END
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C   SUBROUTINE FOR CALLING INPUT DATA AND CALCULATING ROUTINES      C10E 1
      COMMON F10001, NTEGER100, TABLE4(2000,21),
      1      TABLE2(500,11)
      EQUIVALENCE (INTEGER13), MPS1
      EQUIVALENCE (INTEGER48), NZERO
      EQUIVALENCE (REAL51), FACTOR
      IF (NZERO) 60, 10, 5
      10      DO 20 I = 1, 10000
      20      MPS1 = 0.0
      30      DO 30 I = 1, 100
      30      NZERO = 0
      40      GO TO 46
      40      DO 42 I = 1001, 10000
      42      MPS1 = 0.0
      44      FACTOR = 1.0
      44      CALL INPUT
      44      CALL CALC
      44      CALL LDUL
      44      CALL PRINTP
      44      IF (INPT) 40, 60, 50
      50      CALL LDOLF
      50      RETURN
      60
      END

```


--- SUBROUTINE INOUT --- 70476 -0871 ---

30 READ-45,401-INTEOF(I1) 1-17-14) ----- DEFN 262
FORMAT (1I15) DEFN 263
IF (INEOF) 70, 70, 60 DEFN 264
READ 45,401-INTEOF(I1) 1-17-14) ----- DEFN 27
CALL PAGEFO DEFN 28
70 WRITE OUT RUN INFORMATION DEFN 30
C DEFN 31
90 WRITE FAO (5,1,001) DEFN 32
FORMAT (45H DEFN 32
65 102 16H DEFN 33
66 1 16H DEFN 34
67 2 16H DEFN 35
68 3 16H DEFN 36
69 4 16H DEFN 37
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SUBROUTINE INPUT		MAIN %	OPTION	PAGE
115				1
		READ (5,140) (VARIABLE,II), K = 1, NNT13) READ (5,140) (VARIABLE,II), K = NNT1P1, NNT121 READ (5,140) (VARIABLE,II), K = NNT121, NNT131 DEFIN004 DEFIN005		
		DEFIN006 DEFIN007		
		DEFIN008 DEFIN009		
		DEFIN010 DEFIN011		
120	654 655	60 TO 654,656, 1 GO TO 655,660, N70 READ (5,140) (VARIABLE,II), K = NNT1P1, NNT140 READ (5,140) (VARIABLE,II), K = NNT1P1, NNT140 GO TO 670, N70 READ (5,140) NNT183 NNF = NNT13 * NNP READ (5,140) (VARIABLE,II), K = NNT1P1, NFF CONTIN10 CALL IN1AC RETURN END		
		DEFIN012 DEFIN013 DEFIN014 DEFIN015 DEFIN016 DEFIN017 DEFIN018 DEFIN019 DEFIN020 DEFIN021		
125	67C A70			

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SUBROUTINE: INAO13    T4474    OPT=1    FIN 4-9-2353    178273 - 89.0522.

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FTM 4-099353 14/2/73 09:05:28. PAGE 2
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A, N, K33

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115      60      WRITE(10X, 26HGAUSS2) ERROR SIGNAL + K3 * 131
116      70      FORMAT(10X, 26HGAUSS2) ERROR SIGNAL + K3 * 131
117      80      IF (11-111 140, 100, 90
118      81      IF (11-NPL2) 120, 110, 140
119      82      IF (11-NPL2) 120, 110, 140
120      90      P051(1) = 2.0 * X(10) * P51L(1) * X(12)
121      100
122      110      P051(1) = 2.0 * X(11) * P51L(12) * X(12)
123      120      P051(1) = 2.0 * X(11) * P51L(11) * X(12)
124      130      CONTINF
125      140      RETURN
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SUBROUTINE LDVLV 7474 DP74 FIN 4.0P151 11.02.73 - 9.05.83 PAGE 2

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1. AREANINPSILL-111 / 2.0
  RETURN
  END
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  LDVLV 458
  LDVLV 46
  LDVLV 47
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SUBROUTINE XFACT

TWTs - OPT1

FIN. ANALYSIS 11/12/73 A9.05.60. PAGE 1

```

      1   AMP, NTAB1, NTAB2, XFACT
      C   SUBROUTINE XFACT - TABLE, X1ARG, X2ARG, X3ARG
      C   SUBROUTINE FOR STRAIGHT LINE INTERPOLATION IN A TRIPLE
      C   TABLE LOOK UP
      DIMENSION TABLE (7000)
      DO 10 I1 = 1, NTAB1
      IF (TABLE(I11) - X1ARG) 10, 20, 20
      CONTINUE
      I1 = NTAB1
      IF (I11 - 10, 30, 40
      I1 = 2
      NT1P1 = NTAB1 + 1
      MN12 = NTAB1 + NTAB2
      DO 12 I2 = 1, NTAB2
      IF (TABLE(I12) - X2ARG) 10, 20, 20
      CONTINUE
      I2 = NTAB2
      IF (I2 - 112 - 112P1) 70, 70, 60
      I2 = 2
      NT2P1 = NTAB2 + 1
      MN13 = NTAB1 + NTAB3
      DO 13 I3 = 1, NTAB3
      IF (TABLE(I13) - X3ARG) 90, 100, 100
      CONTINUE
      I3 = NTAB3
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SUBROUTINE TABD (TABLE, X1ARG, X2ARG, X3ARG,)
 C KARG, AMP, NTAB1, NTAB2, NTAB3, NTAB4, NTAB5, NTAB6
 C SUBROUTINE FOR STRAIGHT LINE INTERPOLATION IN A QUADRUPLE
 C TABLE LOOK UP
 DIMENSION TABLE (12000)
 DO 10 TI = 1, NTAB1
 IF (TABLE(TI) = X1ARG) 10, 20, 20
 CONTINUE
 TI = NTAB2
 IF (TI = 1) 30, 30, 40
 TI = 2
 NT1P1 = NTAB1 + 1
 NT112 = NTAB1 + NTAB2
 DO 40 TI2 = NTAB1 + NTAB2
 IF (TABLE(TI2) = X2ARG) 50, 50, 50
 CONTINUE
 IF (TI2 = 1) 60, 60, 60
 TI2 = NTAB2
 IF (TI2 = NTAB1) 70, 70, 80
 J2 = NTAB3
 NT2P1 = NTAB2 + 1
 NT113 = NTAB2 + NTAB3
 DO 90 TI3 = NT2P1, NTAB3
 IF (TABLE(TI3) = X3ARG) 90, 100, 100
 CONTINUE
 J3 = NTAB3
 DO 100 TI3 = 1, NTAB3
 IF (TI3 = 1) 110, 110, 120
 TI3 = NTAB2 + 2
 NT3P1 = NTAB3 + 1
 NT114 = NTAB3 + NTAB4
 DO 130 TI4 = NT3P1, NTAB4
 IF (TABLE(TI4) = X4ARG) 110, 140, 140
 CONTINUE
 J4 = NTAB4
 DO 140 TI4 = 1, NTAB4
 IF (TI4 = 1) 150, 150, 160
 TI4 = NTAB3 + 2
 NT4P1 = NTAB4 + 1
 NT115 = NTAB4 + NTAB5
 DO 160 TI5 = NT4P1, NTAB5
 IF (TABLE(TI5) = X5ARG) 110, 110, 110
 CONTINUE
 J5 = NTAB5
 DO 170 TI5 = 1, NTAB5
 IF (TI5 = 1) 180, 180, 190
 TI5 = NTAB4 + 1
 NT5P1 = NTAB5 + 1
 NT116 = NTAB5 + NTAB6
 DO 190 TI6 = NT5P1, NTAB6
 IF (TABLE(TI6) = X6ARG) 110, 110, 110
 CONTINUE
 J6 = NTAB6
 DO 200 TI6 = 1, NTAB6
 IF (TI6 = 1) 210, 210, 220
 TI6 = NTAB5 + 2
 NT6P1 = NTAB6 + 1
 NT117 = NTAB6 + NTAB1
 DO 220 TI7 = NT6P1, NTAB1
 IF (TABLE(TI7) = X7ARG) 210, 210, 220
 CONTINUE
 J7 = NTAB1
 DO 230 TI7 = 1, NTAB1
 IF (TI7 = 1) 240, 240, 250
 TI7 = NTAB0 + 1
 NT7P1 = NTAB1 + 1
 NT118 = NTAB0 + NTAB2
 DO 250 TI8 = NT7P1, NTAB2
 IF (TABLE(TI8) = X8ARG) 240, 240, 250
 CONTINUE
 J8 = NTAB2
 DO 260 TI8 = 1, NTAB2
 IF (TI8 = 1) 270, 270, 280
 TI8 = NTAB1 + 1
 NT8P1 = NTAB2 + 1
 NT119 = NTAB1 + NTAB3
 DO 280 TI9 = NT8P1, NTAB3
 IF (TABLE(TI9) = X9ARG) 270, 270, 280
 CONTINUE
 J9 = NTAB3
 DO 290 TI9 = 1, NTAB3
 IF (TI9 = 1) 300, 300, 310
 TI9 = NTAB2 + 1
 NT9P1 = NTAB3 + 1
 NT120 = NTAB2 + NTAB4
 DO 310 TI10 = NT9P1, NTAB4
 IF (TABLE(TI10) = X10ARG) 300, 300, 310
 CONTINUE
 J10 = NTAB4
 DO 320 TI10 = 1, NTAB4
 IF (TI10 = 1) 330, 330, 340
 TI10 = NTAB3 + 2
 NT10P1 = NTAB4 + 1
 NT121 = NTAB3 + NTAB5
 DO 340 TI11 = NT10P1, NTAB5
 IF (TABLE(TI11) = X11ARG) 330, 330, 340
 CONTINUE
 J11 = NTAB5
 DO 350 TI11 = 1, NTAB5
 IF (TI11 = 1) 360, 360, 370
 TI11 = NTAB4 + 1
 NT11P1 = NTAB5 + 1
 NT122 = NTAB4 + NTAB6
 DO 370 TI12 = NT11P1, NTAB6
 IF (TABLE(TI12) = X12ARG) 360, 360, 370
 CONTINUE
 J12 = NTAB6
 DO 380 TI12 = 1, NTAB6
 IF (TI12 = 1) 390, 390, 400
 TI12 = NTAB5 + 2
 NT12P1 = NTAB6 + 1
 NT123 = NTAB5 + NTAB1
 DO 400 TI13 = NT12P1, NTAB1
 IF (TABLE(TI13) = X13ARG) 390, 390, 400
 CONTINUE
 J13 = NTAB1
 DO 410 TI13 = 1, NTAB1
 IF (TI13 = 1) 420, 420, 430
 TI13 = NTAB0 + 1
 NT13P1 = NTAB1 + 1
 NT124 = NTAB0 + NTAB2
 DO 430 TI14 = NT13P1, NTAB2
 IF (TABLE(TI14) = X14ARG) 420, 420, 430
 CONTINUE
 J14 = NTAB2
 DO 440 TI14 = 1, NTAB2
 IF (TI14 = 1) 450, 450, 460
 TI14 = NTAB1 + 1
 NT14P1 = NTAB2 + 1
 NT125 = NTAB1 + NTAB3
 DO 460 TI15 = NT14P1, NTAB3
 IF (TABLE(TI15) = X15ARG) 450, 450, 460
 CONTINUE
 J15 = NTAB3
 DO 470 TI15 = 1, NTAB3
 IF (TI15 = 1) 480, 480, 490
 TI15 = NTAB2 + 2
 NT15P1 = NTAB3 + 1
 NT126 = NTAB2 + NTAB4
 DO 490 TI16 = NT15P1, NTAB4
 IF (TABLE(TI16) = X16ARG) 480, 480, 490
 CONTINUE
 J16 = NTAB4
 DO 500 TI16 = 1, NTAB4
 IF (TI16 = 1) 510, 510, 520
 TI16 = NTAB3 + 2
 NT16P1 = NTAB4 + 1
 NT127 = NTAB3 + NTAB5
 DO 520 TI17 = NT16P1, NTAB5
 IF (TABLE(TI17) = X17ARG) 510, 510, 520
 CONTINUE
 J17 = NTAB5
 DO 530 TI17 = 1, NTAB5
 IF (TI17 = 1) 540, 540, 550
 TI17 = NTAB4 + 2
 NT17P1 = NTAB5 + 1
 NT128 = NTAB4 + NTAB6
 DO 550 TI18 = NT17P1, NTAB6
 IF (TABLE(TI18) = X18ARG) 540, 540, 550
 CONTINUE
 J18 = NTAB6
 DO 560 TI18 = 1, NTAB6
 IF (TI18 = 1) 570, 570, 580
 TI18 = NTAB5 + 3
 NT18P1 = NTAB6 + 1
 NT129 = NTAB5 + NTAB1
 DO 580 TI19 = NT18P1, NTAB1
 IF (TABLE(TI19) = X19ARG) 570, 570, 580
 CONTINUE
 J19 = NTAB1
 DO 590 TI19 = 1, NTAB1
 IF (TI19 = 1) 600, 600, 610
 TI19 = NTAB0 + 2
 NT19P1 = NTAB1 + 1
 NT130 = NTAB0 + NTAB2
 DO 610 TI20 = NT19P1, NTAB2
 IF (TABLE(TI20) = X20ARG) 600, 600, 610
 CONTINUE
 J20 = NTAB2
 DO 620 TI20 = 1, NTAB2
 IF (TI20 = 1) 630, 630, 640
 TI20 = NTAB1 + 2
 NT20P1 = NTAB2 + 1
 NT131 = NTAB1 + NTAB3
 DO 640 TI21 = NT20P1, NTAB3
 IF (TABLE(TI21) = X21ARG) 630, 630, 640
 CONTINUE
 J21 = NTAB3
 DO 650 TI21 = 1, NTAB3
 IF (TI21 = 1) 660, 660, 670
 TI21 = NTAB2 + 3
 NT21P1 = NTAB3 + 1
 NT132 = NTAB2 + NTAB4
 DO 670 TI22 = NT21P1, NTAB4
 IF (TABLE(TI22) = X22ARG) 660, 660, 670
 CONTINUE
 J22 = NTAB4
 DO 680 TI22 = 1, NTAB4
 IF (TI22 = 1) 690, 690, 700
 TI22 = NTAB3 + 2
 NT22P1 = NTAB4 + 1
 NT133 = NTAB3 + NTAB5
 DO 700 TI23 = NT22P1, NTAB5
 IF (TABLE(TI23) = X23ARG) 690, 690, 700
 CONTINUE
 J23 = NTAB5
 DO 710 TI23 = 1, NTAB5
 IF (TI23 = 1) 720, 720, 730
 TI23 = NTAB4 + 2
 NT23P1 = NTAB5 + 1
 NT134 = NTAB4 + NTAB6
 DO 730 TI24 = NT23P1, NTAB6
 IF (TABLE(TI24) = X24ARG) 720, 720, 730
 CONTINUE
 J24 = NTAB6
 DO 740 TI24 = 1, NTAB6
 IF (TI24 = 1) 750, 750, 760
 TI24 = NTAB5 + 3
 NT24P1 = NTAB6 + 1
 NT135 = NTAB5 + NTAB1
 DO 760 TI25 = NT24P1, NTAB1
 IF (TABLE(TI25) = X25ARG) 750, 750, 760
 CONTINUE
 J25 = NTAB1
 DO 770 TI25 = 1, NTAB1
 IF (TI25 = 1) 780, 780, 790
 TI25 = NTAB0 + 2
 NT25P1 = NTAB1 + 1
 NT136 = NTAB0 + NTAB2
 DO 790 TI26 = NT25P1, NTAB2
 IF (TABLE(TI26) = X26ARG) 780, 780, 790
 CONTINUE
 J26 = NTAB2
 DO 800 TI26 = 1, NTAB2
 IF (TI26 = 1) 810, 810, 820
 TI26 = NTAB1 + 2
 NT26P1 = NTAB2 + 1
 NT137 = NTAB1 + NTAB3
 DO 820 TI27 = NT26P1, NTAB3
 IF (TABLE(TI27) = X27ARG) 810, 810, 820
 CONTINUE
 J27 = NTAB3
 DO 830 TI27 = 1, NTAB3
 IF (TI27 = 1) 840, 840, 850
 TI27 = NTAB2 + 3
 NT27P1 = NTAB3 + 1
 NT138 = NTAB2 + NTAB4
 DO 850 TI28 = NT27P1, NTAB4
 IF (TABLE(TI28) = X28ARG) 840, 840, 850
 CONTINUE
 J28 = NTAB4
 DO 860 TI28 = 1, NTAB4
 IF (TI28 = 1) 870, 870, 880
 TI28 = NTAB3 + 2
 NT28P1 = NTAB4 + 1
 NT139 = NTAB3 + NTAB5
 DO 880 TI29 = NT28P1, NTAB5
 IF (TABLE(TI29) = X29ARG) 870, 870, 880
 CONTINUE
 J29 = NTAB5
 DO 890 TI29 = 1, NTAB5
 IF (TI29 = 1) 900, 900, 910
 TI29 = NTAB4 + 2
 NT29P1 = NTAB5 + 1
 NT140 = NTAB4 + NTAB6
 DO 910 TI30 = NT29P1, NTAB6
 IF (TABLE(TI30) = X30ARG) 900, 900, 910
 CONTINUE
 J30 = NTAB6
 DO 920 TI30 = 1, NTAB6
 IF (TI30 = 1) 930, 930, 940
 TI30 = NTAB5 + 3
 NT30P1 = NTAB6 + 1
 NT141 = NTAB5 + NTAB1
 DO 940 TI31 = NT30P1, NTAB1
 IF (TABLE(TI31) = X31ARG) 930, 930, 940
 CONTINUE
 J31 = NTAB1
 DO 950 TI31 = 1, NTAB1
 IF (TI31 = 1) 960, 960, 970
 TI31 = NTAB0 + 2
 NT31P1 = NTAB1 + 1
 NT142 = NTAB0 + NTAB2
 DO 970 TI32 = NT31P1, NTAB2
 IF (TABLE(TI32) = X32ARG) 960, 960, 970
 CONTINUE
 J32 = NTAB2
 DO 980 TI32 = 1, NTAB2
 IF (TI32 = 1) 990, 990, 1000
 TI32 = NTAB1 + 2
 NT32P1 = NTAB2 + 1
 NT143 = NTAB1 + NTAB3
 DO 1000 TI33 = NT32P1, NTAB3
 IF (TABLE(TI33) = X33ARG) 990, 990, 1000
 CONTINUE
 J33 = NTAB3
 DO 1010 TI33 = 1, NTAB3
 IF (TI33 = 1) 1020, 1020, 1030
 TI33 = NTAB2 + 3
 NT33P1 = NTAB3 + 1
 NT144 = NTAB2 + NTAB4
 DO 1030 TI34 = NT33P1, NTAB4
 IF (TABLE(TI34) = X34ARG) 1020, 1020, 1030
 CONTINUE
 J34 = NTAB4
 DO 1040 TI34 = 1, NTAB4
 IF (TI34 = 1) 1050, 1050, 1060
 TI34 = NTAB3 + 2
 NT34P1 = NTAB4 + 1
 NT145 = NTAB3 + NTAB5
 DO 1060 TI35 = NT34P1, NTAB5
 IF (TABLE(TI35) = X35ARG) 1050, 1050, 1060
 CONTINUE
 J35 = NTAB5
 DO 1070 TI35 = 1, NTAB5
 IF (TI35 = 1) 1080, 1080, 1090
 TI35 = NTAB4 + 2
 NT35P1 = NTAB5 + 1
 NT146 = NTAB4 + NTAB6
 DO 1090 TI36 = NT35P1, NTAB6
 IF (TABLE(TI36) = X36ARG) 1080, 1080, 1090
 CONTINUE
 J36 = NTAB6
 DO 1100 TI36 = 1, NTAB6
 IF (TI36 = 1) 1110, 1110, 1120
 TI36 = NTAB5 + 3
 NT36P1 = NTAB6 + 1
 NT147 = NTAB5 + NTAB1
 DO 1120 TI37 = NT36P1, NTAB1
 IF (TABLE(TI37) = X37ARG) 1110, 1110, 1120
 CONTINUE
 J37 = NTAB1
 DO 1130 TI37 = 1, NTAB1
 IF (TI37 = 1) 1140, 1140, 1150
 TI37 = NTAB0 + 2
 NT37P1 = NTAB1 + 1
 NT148 = NTAB0 + NTAB2
 DO 1150 TI38 = NT37P1, NTAB2
 IF (TABLE(TI38) = X38ARG) 1140, 1140, 1150
 CONTINUE
 J38 = NTAB2
 DO 1160 TI38 = 1, NTAB2
 IF (TI38 = 1) 1170, 1170, 1180
 TI38 = NTAB1 + 2
 NT38P1 = NTAB2 + 1
 NT149 = NTAB1 + NTAB3
 DO 1180 TI39 = NT38P1, NTAB3
 IF (TABLE(TI39) = X39ARG) 1170, 1170, 1180
 CONTINUE
 J39 = NTAB3
 DO 1190 TI39 = 1, NTAB3
 IF (TI39 = 1) 1200, 1200, 1210
 TI39 = NTAB2 + 3
 NT39P1 = NTAB3 + 1
 NT150 = NTAB2 + NTAB4
 DO 1210 TI40 = NT39P1, NTAB4
 IF (TABLE(TI40) = X40ARG) 1200, 1200, 1210
 CONTINUE
 J40 = NTAB4
 DO 1220 TI40 = 1, NTAB4
 IF (TI40 = 1) 1230, 1230, 1240
 TI40 = NTAB3 + 2
 NT40P1 = NTAB4 + 1
 NT151 = NTAB3 + NTAB5
 DO 1240 TI41 = NT40P1, NTAB5
 IF (TABLE(TI41) = X41ARG) 1230, 1230, 1240
 CONTINUE
 J41 = NTAB5
 DO 1250 TI41 = 1, NTAB5
 IF (TI41 = 1) 1260, 1260, 1270
 TI41 = NTAB4 + 2
 NT41P1 = NTAB5 + 1
 NT152 = NTAB4 + NTAB6
 DO 1270 TI42 = NT41P1, NTAB6
 IF (TABLE(TI42) = X42ARG) 1260, 1260, 1270
 CONTINUE
 J42 = NTAB6
 DO 1280 TI42 = 1, NTAB6
 IF (TI42 = 1) 1290, 1290, 1300
 TI42 = NTAB5 + 3
 NT42P1 = NTAB6 + 1
 NT153 = NTAB5 + NTAB1
 DO 1300 TI43 = NT42P1, NTAB1
 IF (TABLE(TI43) = X43ARG) 1290, 1290, 1300
 CONTINUE
 J43 = NTAB1
 DO 1310 TI43 = 1, NTAB1
 IF (TI43 = 1) 1320, 1320, 1330
 TI43 = NTAB0 + 2
 NT43P1 = NTAB1 + 1
 NT154 = NTAB0 + NTAB2
 DO 1330 TI44 = NT43P1, NTAB2
 IF (TABLE(TI44) = X44ARG) 1320, 1320, 1330
 CONTINUE
 J44 = NTAB2
 DO 1340 TI44 = 1, NTAB2
 IF (TI44 = 1) 1350, 1350, 1360
 TI44 = NTAB1 + 2
 NT44P1 = NTAB2 + 1
 NT155 = NTAB1 + NTAB3
 DO 1360 TI45 = NT44P1, NTAB3
 IF (TABLE(TI45) = X45ARG) 1350, 1350, 1360
 CONTINUE
 J45 = NTAB3
 DO 1370 TI45 = 1, NTAB3
 IF (TI45 = 1) 1380, 1380, 1390
 TI45 = NTAB2 + 3
 NT45P1 = NTAB3 + 1
 NT156 = NTAB2 + NTAB4
 DO 1390 TI46 = NT45P1, NTAB4
 IF (TABLE(TI46) = X46ARG) 1380, 1380, 1390
 CONTINUE
 J46 = NTAB4
 DO 1400 TI46 = 1, NTAB4
 IF (TI46 = 1) 1410, 1410, 1420
 TI46 = NTAB3 + 2
 NT46P1 = NTAB4 + 1
 NT157 = NTAB3 + NTAB5
 DO 1420 TI47 = NT46P1, NTAB5
 IF (TABLE(TI47) = X47ARG) 1410, 1410, 1420
 CONTINUE
 J47 = NTAB5
 DO 1430 TI47 = 1, NTAB5
 IF (TI47 = 1) 1440, 1440, 1450
 TI47 = NTAB4 + 2
 NT47P1 = NTAB5 + 1
 NT158 = NTAB4 + NTAB6
 DO 1450 TI48 = NT47P1, NTAB6
 IF (TABLE(TI48) = X48ARG) 1440, 1440, 1450
 CONTINUE
 J48 = NTAB6
 DO 1460 TI48 = 1, NTAB6
 IF (TI48 = 1) 1470, 1470, 1480
 TI48 = NTAB5 + 3
 NT48P1 = NTAB6 + 1
 NT159 = NTAB5 + NTAB1
 DO 1480 TI49 = NT48P1, NTAB1
 IF (TABLE(TI49) = X49ARG) 1470, 1470, 1480
 CONTINUE
 J49 = NTAB1
 DO 1490 TI49 = 1, NTAB1
 IF (TI49 = 1) 1500, 1500, 1510
 TI49 = NTAB0 + 2
 NT49P1 = NTAB1 + 1
 NT160 = NTAB0 + NTAB2
 DO 1510 TI50 = NT49P1, NTAB2
 IF (TABLE(TI50) = X50ARG) 1500, 1500, 1510
 CONTINUE
 J50 = NTAB2
 DO 1520 TI50 = 1, NTAB2
 IF (TI50 = 1) 1530, 1530, 1540
 TI50 = NTAB1 + 2
 NT50P1 = NTAB2 + 1
 NT161 = NTAB1 + NTAB3
 DO 1540 TI51 = NT50P1, NTAB3
 IF (TABLE(TI51) = X51ARG) 1530, 1530, 1540
 CONTINUE
 J51 = NTAB3
 DO 1550 TI51 = 1, NTAB3
 IF (TI51 = 1) 1560, 1560, 1570
 TI51 = NTAB2 + 3
 NT51P1 = NTAB3 + 1
 NT162 = NTAB2 + NTAB4
 DO 1570 TI52 = NT51P1, NTAB4
 IF (TABLE(TI52) = X52ARG) 1560, 1560, 1570
 CONTINUE
 J52 = NTAB4
 DO 1580 TI52 = 1, NTAB4
 IF (TI52 = 1) 1590, 1590, 1600
 TI52 = NTAB3 + 2
 NT52P1 = NTAB4 + 1
 NT163 = NTAB3 + NTAB5
 DO 1600 TI53 = NT52P1, NTAB5
 IF (TABLE(TI53) = X53ARG) 1590, 1590, 1600
 CONTINUE
 J53 = NTAB5
 DO 1610 TI53 = 1, NTAB5
 IF (TI53 = 1) 1620, 1620, 1630
 TI53 = NTAB4 + 2
 NT53P1 = NTAB5 + 1
 NT164 = NTAB4 + NTAB6
 DO 1630 TI54 = NT53P1, NTAB6
 IF (TABLE(TI54) = X54ARG) 1620, 1620, 1630
 CONTINUE
 J54 = NTAB6
 DO 1640 TI54 = 1, NTAB6
 IF (TI54 = 1) 1650, 1650, 1660
 TI54 = NTAB5 + 3
 NT54P1 = NTAB6 + 1
 NT165 = NTAB5 + NTAB1
 DO 1660 TI55 = NT54P1, NTAB1
 IF (TABLE(TI55) = X55ARG) 1650, 1650, 1660
 CONTINUE
 J55 = NTAB1
 DO 1670 TI55 = 1, NTAB1
 IF (TI55 = 1) 1680, 1680, 1690
 TI55 = NTAB0 + 2
 NT55P1 = NTAB1 + 1
 NT166 = NTAB0 + NTAB2
 DO 1690 TI56 = NT55P1, NTAB2
 IF (TABLE(TI56) = X56ARG) 1680, 1680, 1690
 CONTINUE
 J56 = NTAB2
 DO 1700 TI56 = 1, NTAB2
 IF (TI56 = 1) 1710, 1710, 1720
 TI56 = NTAB1 + 2
 NT56P1 = NTAB2 + 1
 NT167 = NTAB1 + NTAB3
 DO 1720 TI57 = NT56P1, NTAB3
 IF (TABLE(TI57) = X57ARG) 1710, 1710, 1720
 CONTINUE
 J57 = NTAB3
 DO 1730 TI57 = 1, NTAB3
 IF (TI57 = 1) 1740, 1740, 1750
 TI57 = NTAB2 + 3
 NT57P1 = NTAB3 + 1
 NT168 = NTAB2 + NTAB4
 DO 1750 TI58 = NT57P1, NTAB4
 IF (TABLE(TI58) = X58ARG) 1740, 1740, 1750
 CONTINUE
 J58 = NTAB4
 DO 1760 TI58 = 1, NTAB4
 IF (TI58 = 1) 1770, 1770, 1780
 TI58 = NTAB3 + 2
 NT58P1 = NTAB4 + 1
 NT169 = NTAB3 + NTAB5
 DO 1780 TI59 = NT58P1, NTAB5
 IF (TABLE(TI59) = X59ARG) 1770, 1770, 1780
 CONTINUE
 J59 = NTAB5
 DO 1790 TI59 = 1, NTAB5
 IF (TI59 = 1) 1800, 1800, 1810
 TI59 = NTAB4 + 2
 NT59P1 = NTAB5 + 1
 NT170 = NTAB4 + NTAB6
 DO 1810 TI60 = NT59P1, NTAB6
 IF (TABLE(TI60) = X60ARG) 1800, 1800, 1810
 CONTINUE
 J60 = NTAB6
 DO 1820 TI60 = 1, NTAB6
 IF (TI60 = 1) 1830, 1830, 1840
 TI60 = NTAB5 + 3
 NT60P1 = NTAB6 + 1
 NT171 = NTAB5 + NTAB1
 DO 1840 TI61 = NT60P1, NTAB1
 IF (TABLE(TI61) = X61ARG) 1830, 1830, 1840
 CONTINUE
 J61 = NTAB1
 DO 1850 TI61 = 1, NTAB1
 IF (TI61 = 1) 1860, 1860, 1870
 TI61 = NTAB0 + 2
 NT61P1 = NTAB1 + 1
 NT172 = NTAB0 + NTAB2
 DO 1870 TI62 = NT61P1, NTAB2
 IF (TABLE(TI62) = X62ARG) 1860, 1860, 1870
 CONTINUE
 J62 = NTAB2
 DO 1880 TI62 = 1, NTAB2
 IF (TI62 = 1) 1890, 1890, 1900
 TI62 = NTAB1 + 2
 NT62P1 = NTAB2 + 1
 NT173 = NTAB1 + NTAB3
 DO 1900 TI63 = NT62P1, NTAB3
 IF (TABLE(TI63) = X63ARG) 1890, 1890, 1900
 CONTINUE
 J63 = NTAB3
 DO 1910 TI63 = 1, NTAB3
 IF (TI63 = 1) 1920, 1920, 1930
 TI63 = NTAB2 + 3
 NT63P1 = NTAB3 + 1
 NT174 = NTAB2 + NTAB4
 DO 1930 TI64 = NT63P1, NTAB4
 IF (TABLE(TI64) = X64ARG) 1920, 1920, 1930
 CONTINUE
 J64 = NTAB4
 DO 1940 TI64 = 1, NTAB4
 IF (TI64 = 1) 1950, 1950, 1960
 TI64 = NTAB3 + 2
 NT64P1 = NTAB4 + 1
 NT175 = NTAB3 + NTAB5
 DO 1960 TI65 = NT64P1, NTAB5
 IF (TABLE(TI65) = X65ARG) 1950, 1950, 1960
 CONTINUE
 J65 = NTAB5
 DO 1970 TI65 = 1, NTAB5
 IF (TI65 = 1) 1980, 1980, 1990
 TI65 = NTAB4 + 2
 NT65P1 = NTAB5 + 1
 NT176 = NTAB4 + NTAB6
 DO 1990 TI66 = NT65P1, NTAB6
 IF (TABLE(TI66) = X66ARG) 1980, 1980, 1990
 CONTINUE
 J66 = NTAB6
 DO 2000 TI66 = 1, NTAB6
 IF (TI66 = 1) 2010, 2010, 2020
 TI66 = NTAB5 + 3
 NT66P1 = NTAB6 + 1
 NT177 = NTAB5 + NTAB1
 DO 2020 TI67 = NT66P1, NTAB1
 IF (TABLE(TI67) = X67ARG) 2010, 2010, 2020
 CONTINUE
 J67 = NTAB1
 DO 2030 TI67 = 1, NTAB1
 IF (TI67 = 1) 2040, 2040, 2050
 TI67 = NTAB0 + 2
 NT67P1 = NTAB1 + 1
 NT178 = NTAB0 + NTAB2
 DO 2050 TI68 = NT67P1, NTAB2
 IF (TABLE(TI68) = X68ARG) 2040, 2040, 2050
 CONTINUE
 J68 = NTAB2
 DO 2060 TI68 = 1, NTAB2
 IF (TI68 = 1) 2070, 2070, 2080
 TI68 = NTAB1 + 2
 NT68P1 = NTAB2 + 1
 NT179 = NTAB1 + NTAB3
 DO 2080 TI69 = NT68P1, NTAB3
 IF (TABLE(TI69) = X69ARG) 2070, 2070, 2080
 CONTINUE
 J69 = NTAB3
 DO 2090 TI69 = 1, NTAB3
 IF (TI69 = 1) 2100, 2100, 2110
 TI69 = NTAB2 + 3
 NT69P1 = NTAB3 + 1
 NT180 = NTAB2 + NTAB4
 DO 2110 TI70 = NT69P1, NTAB4
 IF (TABLE(TI70) = X70ARG) 2100, 2100, 2110
 CONTINUE
 J70 = NTAB4
 DO 2120 TI70 = 1, NTAB4
 IF (TI70 = 1) 2130, 2130, 2140
 TI70 = NTAB3 + 2
 NT70P1 = NTAB4 + 1
 NT181 = NTAB3 + NTAB5
 DO 2140 TI71 = NT70P1, NTAB5
 IF (TABLE(TI71) = X71ARG) 2130, 2130, 2140
 CONTINUE
 J71 = NTAB5
 DO 2150 TI71 = 1, NTAB5
 IF (TI71 = 1) 2160, 2160, 2170
 TI71 = NTAB4 + 2
 NT71P1 = NTAB5 + 1
 NT182 = NTAB4 + NTAB6
 DO 2170 TI72 = NT71P1, NTAB6
 IF (TABLE(TI72) = X72ARG) 2160, 2160, 2170
 CONTINUE
 J72 = NTAB6

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GAUSS2(M,EP1,EP2,EP3)
DIMENSION A(3,4), X(3,1)

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      KPN=4*M
      DO 36 L=1,N
      KP=0
      P=0.0
      DO 12 K=L,N
      IF(12-KPN)13,12,12
      11 Z=0.0
      12 CONTINUE
      RF(1-L-KP)13,20,20
      13 NC=14-J-L,NPN=1
      Z=ALL,JI
      ALL,JI=A(KP,JI)
      15
      16 A(KP,JI)=2
      17 IF(14-S(L-1,JI),L1)-EP150,50,30
      18 IF(1-L-S(L-1,JI),L1)-EP151,51,31
      19 L=1-L
      20
      21 L=1-L
      22
      23 K=LP1,N
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SUBROUTINE GAUS21(M,N,EP,AV,KERB)
  DIMENSION A(125,20), X(125,25)
  NEM144M
  M=1
  N=34 L=1,N
  MP=0
  Z=0,0
  10 12 KAL,N
  IF (Z>ANS) KAL=L,0,11,12,12
  11 2=185 (A(L,K,L))
  12 K=P=X
  13 CONTINUE
  IF (L-KP1) 3,20,20
  14 IN 16 J=L,NPM
  15 7=A(L,J)
  A(L,J)=A(L,P,J)
  16 A(L,P,J)=Z
  20 Z=1.45*(A(L,L))-EP150,50,30
  21 Z=1.45*(A(L,L))-EP150,50,30
  22 Z=1.45*(A(L,L))-EP150,50,30
  23 Z=1.45*(A(L,L))-EP150,50,30
  24 Z=1.45*(A(L,L))-EP150,50,30
  25 Z=1.45*(A(L,L))-EP150,50,30
  26 Z=1.45*(A(L,L))-EP150,50,30
  27 Z=1.45*(A(L,L))-EP150,50,30
  28 Z=1.45*(A(L,L))-EP150,50,30
  29 Z=1.45*(A(L,L))-EP150,50,30
  30 Z=1.45*(A(L,L))-EP150,50,30
  31 Z=1.45*(A(L,L))-EP150,50,30
  32 Z=1.45*(A(L,L))-EP150,50,30
  33 Z=1.45*(A(L,L))-EP150,50,30
  34 Z=1.45*(A(L,L))-EP150,50,30
  35 Z=1.45*(A(L,L))-EP150,50,30
  36 Z=1.45*(A(L,L))-EP150,50,30
  37 Z=1.45*(A(L,L))-EP150,50,30
  38 Z=1.45*(A(L,L))-EP150,50,30
  39 Z=1.45*(A(L,L))-EP150,50,30
  40 Z=1.45*(A(L,L))-EP150,50,30
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  46 Z=1.45*(A(L,L))-EP150,50,30
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  51 Z=1.45*(A(L,L))-EP150,50,30
  52 Z=1.45*(A(L,L))-EP150,50,30
  53 Z=1.45*(A(L,L))-EP150,50,30
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  57 Z=1.45*(A(L,L))-EP150,50,30
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  59 Z=1.45*(A(L,L))-EP150,50,30
  60 Z=1.45*(A(L,L))-EP150,50,30
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  62 Z=1.45*(A(L,L))-EP150,50,30
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  68 Z=1.45*(A(L,L))-EP150,50,30
  69 Z=1.45*(A(L,L))-EP150,50,30
  70 Z=1.45*(A(L,L))-EP150,50,30
  71 Z=1.45*(A(L,L))-EP150,50,30
  72 Z=1.45*(A(L,L))-EP150,50,30
  73 Z=1.45*(A(L,L))-EP150,50,30
  74 Z=1.45*(A(L,L))-EP150,50,30
  75 C=M144F
  RETURN
  END
  GAUS 001
  GAUS 002
  GAUS 004
  GAUS 005
  GAUS 007
  GAUS 008
  GAUS 009
  GAUS 010
  GAUS 011
  GAUS 012
  GAUS 015
  GAUS 016
  GAUS 017
  GAUS 018
  GAUS 019
  GAUS 020
  GAUS 021
  GAUS 022
  GAUS 023
  GAUS 024
  GAUS 025
  GAUS 026
  GAUS 027
  GAUS 028
  GAUS 029
  GAUS 030
  GAUS 031
  GAUS 032
  GAUS 033
  GAUS 034
  GAUS 035
  GAUS 036
  GAUS 037
  GAUS 038
  GAUS 039
  GAUS 040

```


SHARQUSINE PRINTER

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OPT1

FIN. 6.2.921

PAGE 2

```
1 PAGE 8. PAGE 3.  
CALL PAGE0  
60  
60 FORMATT/100.  
WRITE 16,00  
20HCYCIC LOADING.FRACTIONS.)  
WRITE (6,70)  
70 FORMATS (15), UNLOAD, 5X, UNLOAD, 5X,  
- UNLOAD, 5X, UNLOAD, 5X, UNLOAD, 5X,  
DD 80 1 = 1, MPSILL, 3  
11 = 1, 1  
12 = 1, 2  
80 WRITE (6,30) PSILL(1), PSILL(1),  
PSILL(1), PSILL(1), PSILL(1),  
PSILL(1),  
80 MPSILL(12), HYAC(12)  
90 WRITE (6,50) NT  
FORMAT(1/10), 19-INITIAL LOAD CYCLES =, F12.00  
RETURN  
END  
PONI 61
```